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Guadalupe River, California, Sedimentation Study

Numerical Model Investigation

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Final report

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Preface

This sedimentation study for the Guadalupe River in San Jose, CA, was conducted at the Coastal and Hydraulics Laboratory (CHL), Vicksburg, MS, of the U.S. Army Engineer Research and Development Center (ERDC) at the request of the U.S. Army Engineer District, Sacramento.

This investigation was conducted during the period December 2000 to November 2001 under the direction of Mr. Thomas W. Richardson, Director of CHL, Mr. Thomas J. Pokrefke, Acting Deputy Director of CHL, Dr. Yen-Hsi Chu, former Chief of the River Engineering Branch, CHL, and Mr. James Leech, current Chief of the River Engineering Branch, CHL. The principal investigator for the work unit was Dr. Ronald R. Copeland, CHL.

During the course of this study, close working contact was maintained among engineers at the Sacramento District and ERDC. The project engineer at the Sacramento District was Mr. Charles Mifkovic. Independent technical review was provided during the conduct of the study by Drs. Robert Mussetter, Mussetter Engineering, Fort Collins, CO; Roy Richardson, Philip Williams and Associates, San Francisco, CA; and Bill Annable, University of Waterloo, Canada. This report was prepared by Dr. Ronald R. Copeland, CHL, and Ms. Dinah N. McComas, CHL.

At the time of publication of this report, Dr. James R. Houston was Director of ERDC, and COL John W. Morris III, EN, was Commander and Executive Director.

Conversion Factors, Non-SI to SI Units of Measurement

Multiply	By	To Obtain
acre-feet	1,233.489	cubic meters
cubic feet	0.02831685	cubic meters
cubic yards	0.7645549	cubic meters
degrees Fahrenheit	5/9	degrees Celsius of kelvins[1]
feet	0.3048	meters
miles (U.S statute)	1.609347	kilometers
square miles	2,589,998.0	square meters

[1] To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain kelvin (K) reaings, use: $K = (5/9)(F - 32) + 273.15$.

1 Introduction

Background

The Guadalupe River basin is located in Santa Clara County, CA. It has a drainage area of about 160 mi^2 at Alviso near San Francisco Bay and 144 mi^2 below the confluence with Los Gatos Creek. The Santa Cruz Mountains bound the basin on the west and the Diablo Range on the east. High and steep natural slopes characterize the basin's headwaters. Elevations in the basin range from sea level to 3,800 ft. The river drains north through the heavily populated Santa Clara Valley and eventually into San Francisco Bay. Major tributaries of the Guadalupe River are Alamitos Creek, Canoas Creek, and Los Gatos Creek. Figure 1 is a map showing the major features of the Guadalupe River basin.

Reservoirs control about 40 percent of the watershed. These are primarily water supply reservoirs designed to capture winter rains for the purpose of recharging groundwater aquifers. None of the reservoirs have space allocated for flood-control purposes. However, early in the flood season, when space is available, there may be some reduction in flood peaks (U.S. Army Engineer District, San Francisco, 1977). The reservoirs capture most of the sediment supply from the steepest portions of the watershed. Reservoirs located in the drainage basin are listed in the following tabulation.

Reservoirs in the Guadalupe River Watershed			
	Drainage Area above Reservoir mi^2	Storage Capacity acre feet	Year Constructed
Lexington	37	20,200	1952
Guadalupe	6	3,700	1935
Almaden	12	1,800	1935
Calero	8	10,160	1935

The drainage area downstream from the reservoirs is primarily valley land, which has become heavily urbanized. The valley was primarily agricultural prior to 1950. Since then, industrial expansion and urban development has led to significant encroachment into the riparian corridor. The population of Santa Clara County doubled between 1960 and 1980, while the city of San Jose became the
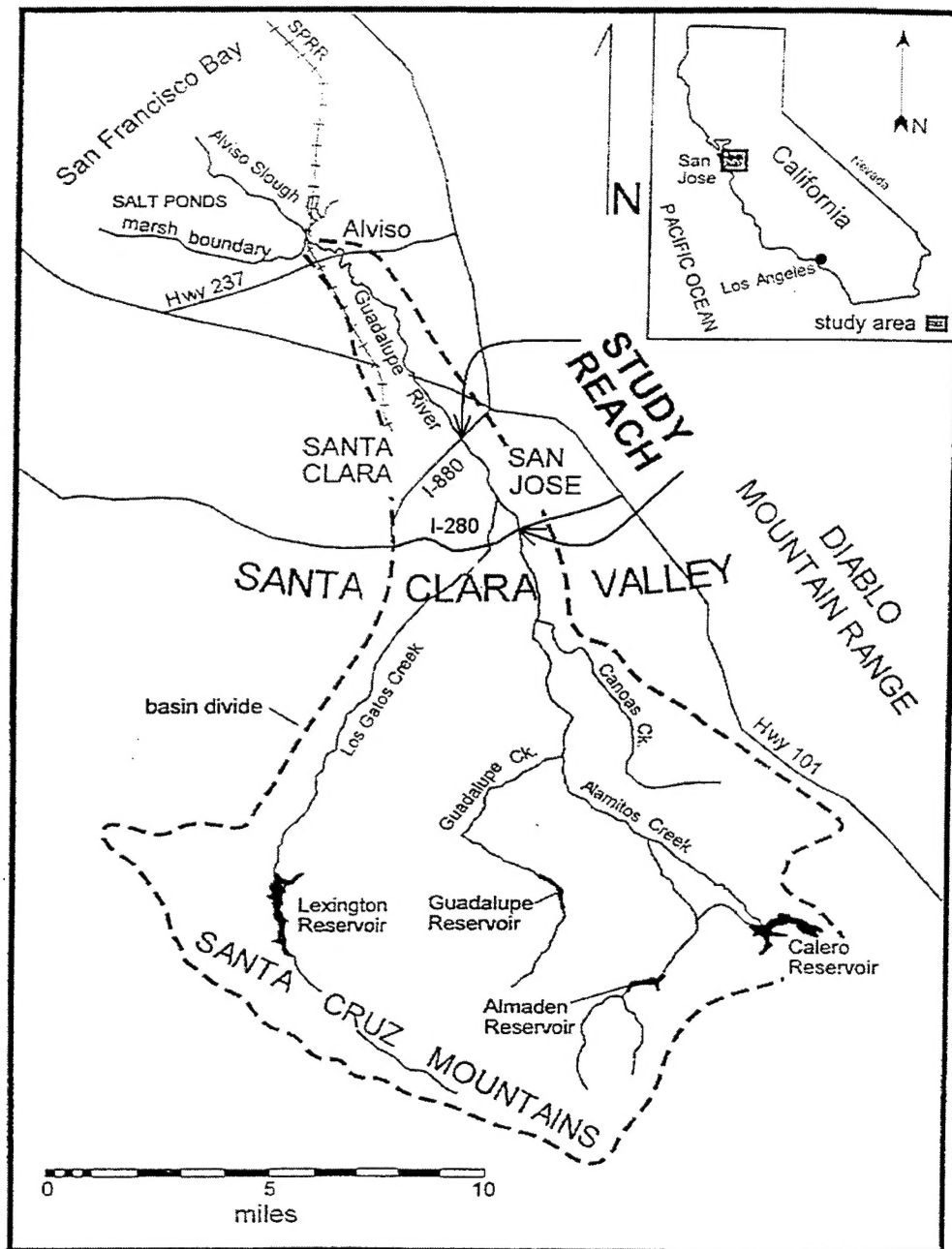
Figure 1.   Study area map showing major features of Guadalupe River basin
(From Northwest Hydraulic Consultants 2000)

third largest city in California. Roads, bridges, and channel stabilization works
exert control on the channel planform. Urbanization has increased both the flood
peaks and runoff volume (USAED, San Francisco, 1977).

The climate in the Santa Clara Valley is characterized by warm, dry summers
and mild, wet winters, with 90 percent of the annual precipitation occurring in the
late fall and winter months. Temperatures range from an average high of 81 °F in
July to an average low of 49 °F in January.

The Santa Clara Valley has experienced regional land subsidence since at least 1906 (Northwest Hydraulic Consultants 2000). About 14 ft of subsidence has been measured in downtown San Jose. Much of this subsidence is attributed to large-scale groundwater overdraft that occurred prior to 1965, the year that state water deliveries began to arrive in the San Jose area. Since 1965 the rate of subsidence has decreased substantially. Land subsidence has affected the bed slope of the Guadalupe River through the study reach.

The reach of the Guadalupe River studied in this report extends 3 miles, between Interstate Highway 280 on the south and Interstate Highway 880 on the north. This reach encompasses much of downtown San Jose. The U.S. Army Corps of Engineers project proposed for this reach of the river is a multipurpose project including both recreation and flood-control benefits. Ultimately, it will be part of a regional park and trail system that will extend over 20 miles along the Guadalupe River. Key features of the project are diversion weirs and box culverts that will bypass flood flows. These permit the existing river channel to be left in a natural-looking setting through a large portion of downtown San Jose, as shown in Figure 2.

Figure 2.   Guadalupe River downstream from Woz Way, March 2001

The banks of the Guadalupe River throughout the length of the study reach are typical of incised channels. Evidence of incision include toe erosion along straight channel reaches as shown in Figure 3 and failure of structures due to undermining as shown in Figure 4. These characteristics were determined during field reconnaissance for this study, and they confirmed observations of previous investigators (Water Engineering and Technology, Inc., (WET) 1991). The banks are steep, sometimes nearly vertical. The banks are composed of erosion resistant silty clays, clayey silts and silty sands and support dense vegetation. Although the
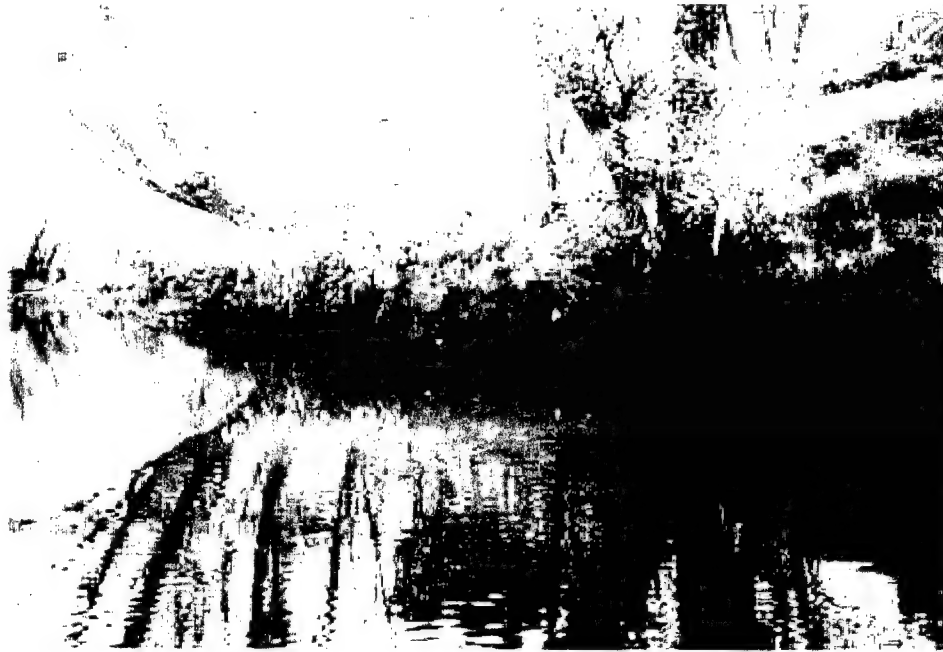
Figure 3.   Bank erosion on right bank between Julian and St. John Streets,
March 2001

Figure 4.   Failure at side-drainage inlet structure downstream from Coleman
Avenue, March 2001

vegetation and cohesive soil properties provide for increased bank stability, bank erosion does occur along the incised channel as shown in Figure 5. Along most of the study reach, the channel bed has a layer of fluvial deposits that consists of sands, gravels, and cobbles. Underlying these deposits are consolidated esturine bay muds, composed of stiff clay and silt deposits that are much more erosion resistant than the relatively thin layer of fluvial sands and gravels that exist on the bed surface. Data from core sampling in the project reach are reported in USAED, Sacramento (1991) and WET (1991). The cohesive layers provide vertical resistance to degradation. Rock and rubble have been dumped across the bed of the Guadalupe River at many locations to provide protection from channel degradation. Some of these bed control structures have been in place for 50 years.

Figure 5.   Bank erosion upstream from Taylor Street, March 2001

Purpose of Numerical Model Study

The objective of this study was to evaluate the potential impact that the Guadalupe River flood-control project would have on channel stability in terms of channel aggradation and degradation. Features of the proposed flood-control project are shown in Figure 6. Both long-term channel response and response during flood events were estimated. The focus of the study was to compare channel response with existing channel conditions to channel response with the flood-control features in place. Data were insufficient to develop a calibrated numerical model that could be used to produce reliable quantified predictions of channel response. However, sensitivity of the numerical model predictions to boundary conditions were determined so that channel responses with and without
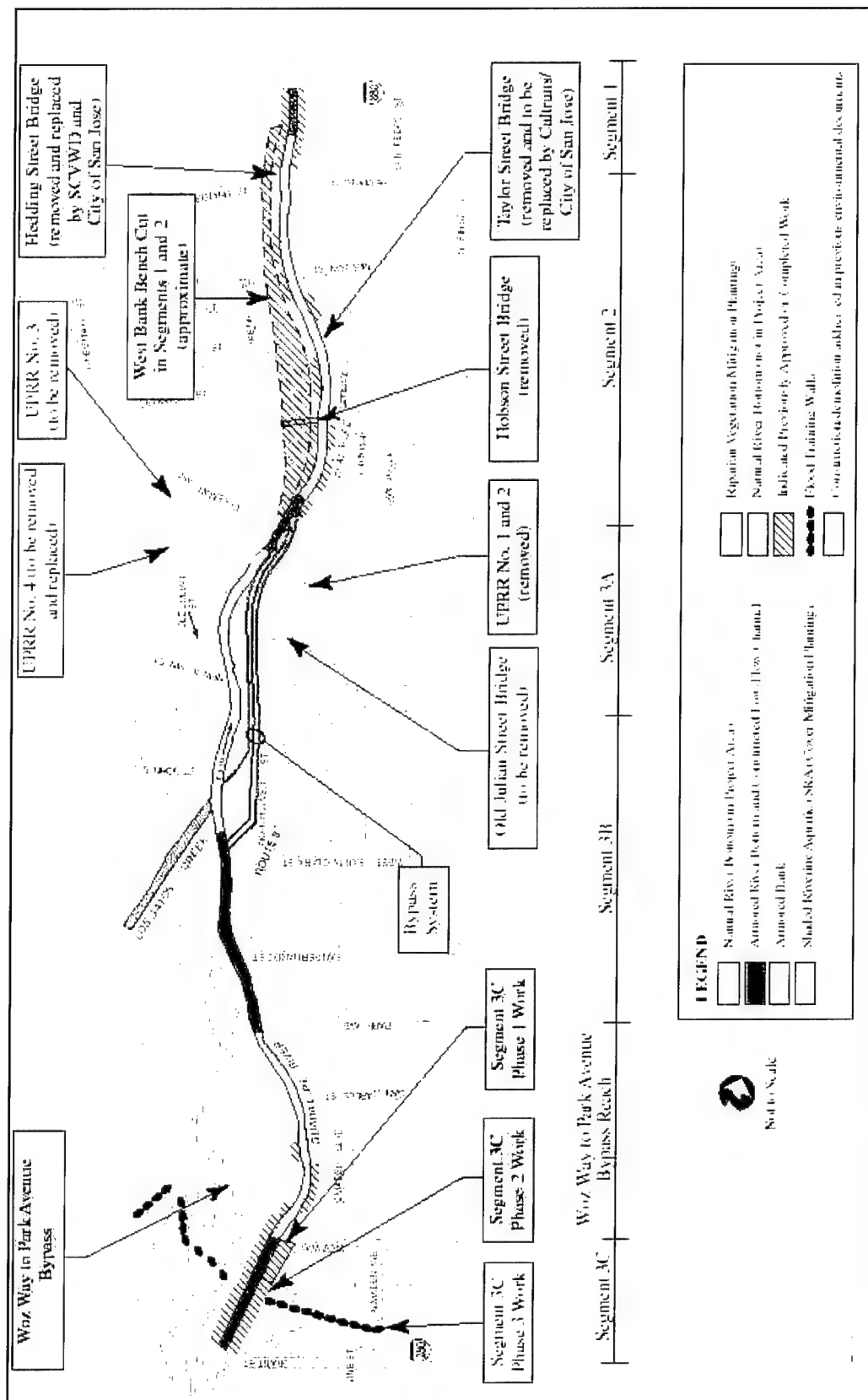
Figure 6.   Guadalupe River bypass alternative for flood protection and onsite mitigation

the project could be compared with confidence. Specific areas of concern were: (a) sediment deposition downstream from bypass inlets during flood events, (b) increased degradation in the channel downstream from bypass outlets where relatively sediment-free flow would be returned to the channel, and (c) increased degradation in reaches where bypasses would not reduce channel flows. Due to limited resources, the study was conducted using available data.

Sedimentation problems that may result as a consequence of the proposed flood-control project on the Guadalupe River were determined by evaluating existing data and using the HEC-6W one-dimensional numerical sedimentation model. Models were developed representing both existing conditions and project conditions in the study reach. The study reach extended between Interstate Highways I-880 and I-280. The numerical sedimentation study quantified the effects of proposed project features on potential aggradation and degradation in the project reach and compared them with those calculated for existing conditions. Sedimentation effects were determined for several flood hydrographs and a long-term hydrograph. The numerical models developed in this study were based on previous unpublished work conducted by USACE, Sacramento (2000).

2 Numerical Model

Numerical Model Description

The HEC-6W one-dimensional numerical sedimentation model was used to make predictions in this study. Mr. William A. Thomas initiated development of this computer program at the U.S. Army Engineer District, Little Rock, in 1967. Further development at the U.S. Army Engineer Hydrologic Engineering Center by Mr. Thomas produced the widely used HEC-6 generalized computer program for calculating scour and deposition in rivers and reservoirs. Additional modification and enhancement to the basic program by Mr. Thomas and his associates at the U.S. Army Engineer Research and Development Center (ERDC) led to the HEC-6W program currently in use. The program produces a one-dimensional model that simulates the response of the riverbed profile to sediment inflow, bed-material gradation, and hydraulic parameters. The model simulates a series of steady-state discharge events, their effects on the sediment transport capacity at cross sections and the resulting degradation or aggradation. The program calculates hydraulic parameters using a standard-step backwater method.

HEC-6W is a state-of-the-art program for use in mobile bed channels. The numerical model computations account for all the basic processes of sedimentation: erosion, entrainment, transportation, deposition, and compaction of the bed for the range of particle sizes found in the Guadalupe River. The model calculates aggradation and degradation of the streambed profile over the course of a hydrologic event. It does not simulate bank erosion or natural adjustments in channel widths. When applied by experts using good engineering judgment, the HEC-6W program will provide good insight into the behavior of mobile bed rivers such as the Guadalupe River.

Geometry

The numerical model developed for this study simulated 3 miles of the Guadalupe River between I-880 and I-280. An additional 1.5 miles of the Guadalupe River upstream from I-280 was modeled as a supply reach.

Cross-section geometry for the numerical model was developed from available data. Unfortunately, there were no homologous surveys for the study

reach. Recent survey data (1997-1999) had to be supplemented by both field observations and older (1987) survey data. Channel widths are accurately modeled in the numerical model, but in reaches where degradation is occurring, the older surveys do not reflect bed elevations temporally consistent with the more recent surveys. The numerical model should calculate scour at accelerated rates for cross sections developed from the older survey data in degrading reaches. Because of the temporally inconsistent data, it was not possible to adjust the numerical model to reproduce historical degradation and aggradation. Rather the numerical model was adjusted to reproduce observed general trends in the study reach. Thus, study results should be used to compare existing and project conditions to determine general sedimentation effects and channel response due to the project and not to predict future degradation or aggradation quantities.

Geometry for the "existing conditions" numerical model was based on cross sections obtained from the 2000 Sacramento District (SPK) HEC-6 model, EC100.DAT, a 1993 SPK HEC-6 model, CWDF.DAT, and a 1995 SPK HEC-2 model G7XABC13.DAT. Cross sections from EC100.DAT were used between I-880 (sta 64+00) and Coleman Avenue (sta 120+00). These cross sections reflect project conditions, including new bridges at Taylor Street (sta 99+00) and Hedding Street (sta 79+00). The channel geometry in this reach was based on 1987 survey data. The overbank geometry was based on construction plans and postconstruction field observations. Cross sections between sta 120+99, which is just upstream from Coleman Avenue, and 125+79 came from both EC100.DAT and G7XABC13.DAT and include both 1987 and 1997-99 channel geometry. In this reach the 1987 survey data were modified by the Sacramento District to account for the fact that the survey did not necessarily provide a complete definition of the underwater portion of the channel. In addition, cross sections in this reach were modified by ERDC so that the base widths were similar to those surveyed in this reach in 1999. Between sta 126+80 and 152+50, just upstream from the Los Gatos Creek confluence, cross sections were based on 1997-1999 survey data. Between Santa Clara Street, at sta 155+00, and I-280, at sta 199+00, cross section geometry is from G7XABC13.DAT and reflects 1987 survey data modified to reflect channel modifications constructed between Park Avenue (sta 170+00) and San Carlos Street (sta 177+00), and between Woz Way (sta 190+50) and I-280 (sta 199+00). Cross sections from G7XABC13.DAT and EC100.DAT are identical between 183+58 and 199+05. Upstream from I-280, cross sections are based on 1987 survey data from CWDF.DAT.

Hydraulic Roughness

Hydraulic roughness in the numerical model was accounted for by using Manning's roughness coefficients. In the natural channel, roughness coefficients were varied with discharge. Water-surface elevations obtained by the Sacramento District during the recession of the January 1995 flood were used to determine composite channel roughness coefficients for the observed discharge. Channel roughness for other discharges was calculated using the Einstein-Horton (Chow 1959 and USACE 1994) compositing equation. Representative cross sections were used in several reaches. First, bank roughness was calculated for the

observed discharge using the composite roughness coefficients and a bed roughness calculated from the Limerinos (1970) equation. Then, using the calculated bank roughness, a composite channel roughness and discharge were calculated for the bankfull condition.

In the improved channel reaches, between Park Avenue and San Carlos Street and between Woz Way and I-280, a design channel roughness of 0.043 was used for all discharges. Design roughness coefficients of 0.050 were also used for all discharges in the reach between sta 114+84 and Coleman Avenue, where several weir structures have been constructed.

Upstream from I-280, channel roughness in the numerical model did not vary with discharge and the assigned values from CWDF.DAT were generally used. However, in the reach between I-280 and the Southern Pacific Railroad bridge the channel hydraulic roughness was increased to 0.065 to be consistent with downstream natural reaches.

Overbank roughness downstream from Coleman Avenue was taken from EC100.DAT. The Manning's roughness coefficients in this reach were determined by the Sacramento District based on field observations and project plans. Overbank roughness for the rest of the numerical model was assigned to be equivalent to bank hydraulic roughness.

Composite roughness determination

High-water marks were obtained between 13:00 and 15:00 on 10 January 1995 during the recession of a 9,300 cfs-peak-discharge flood. Ten high-water marks were collected. Data collection started at the downstream end of the project reach. The high-water marks were taken at bridges and distances were measured in the field to the top of the bridge sidewalk. Actual elevations were later determined in the office using topographic maps developed from aerial photos. These elevations should be considered approximate at best. Only the data upstream from Coleman Avenue were used in this evaluation, because in 1995, the project reach downstream from Coleman Avenue was under construction and did not reflect existing (2001) conditions.

Discharges at the time of data collection were determined using 15-min gage data from the U.S. Geological Survey (USGS) gage upstream from St. John Street, and the Santa Clara Valley Water District gage on Los Gatos Creek at Lincoln Avenue. The discharge downstream from the Los Gatos Creek confluence was estimated to be 4,700 cfs. Upstream from the confluence the discharge was estimated to be 3,500 cfs.

Hydraulic roughness of the bed surface was determined using the Limerinos equation. This equation was developed for gravel-bed rivers where form roughness was insignificant. Bed material gradations in the study reach indicated that the d_{84} was about 35 mm.

$$n_{bed} = \frac{0.0926 \; R^{1/6}}{1.16 \; + \; 2.0 \quad \log \left(R / d_{84} \right)} \tag{1}$$

where:

n_{bed} = bed roughness coefficient

R = hydraulic radius - ft

d_{84} = grain size for which 84 percent of the bed is finer - ft

Calculated bed roughness is tabulated as follows:

R, ft	n
0.5	.034
1.0	.030
2.0	.028
5.0	.027
10.0	.027

At very low discharges, where the water depth is less than about 1 ft, bank roughness is insignificant. Calculations at representative cross sections indicated that the water depth would be about 1 ft deep at a discharge of about 100 cfs. In the discharge-roughness rating tables for natural reaches, discharges of 100 cfs and less were assigned a roughness coefficient of 0.030. In the composite roughness calculations, lower bed roughness values were assigned to the bed because the depth was greater.

Initial values for composite channel roughness were determined iteratively using initial channel cross sections. The water-surface elevation at Coleman Avenue was assigned based on the field-determined high-water mark. Once roughness variability with discharge was determined with the initial cross-section geometry, a second calculation was made with the channel geometry calculated after running the October 1992 to 10 Jan 95 hydrograph. This allowed for model cross-section adjustment and bed response due to the flood. Again channel roughness was adjusted iteratively. This refinement resulted in a slight increase in roughness coefficients. Final calculated water-surface elevations are compared to the measured water-surface elevations in Figure 7.

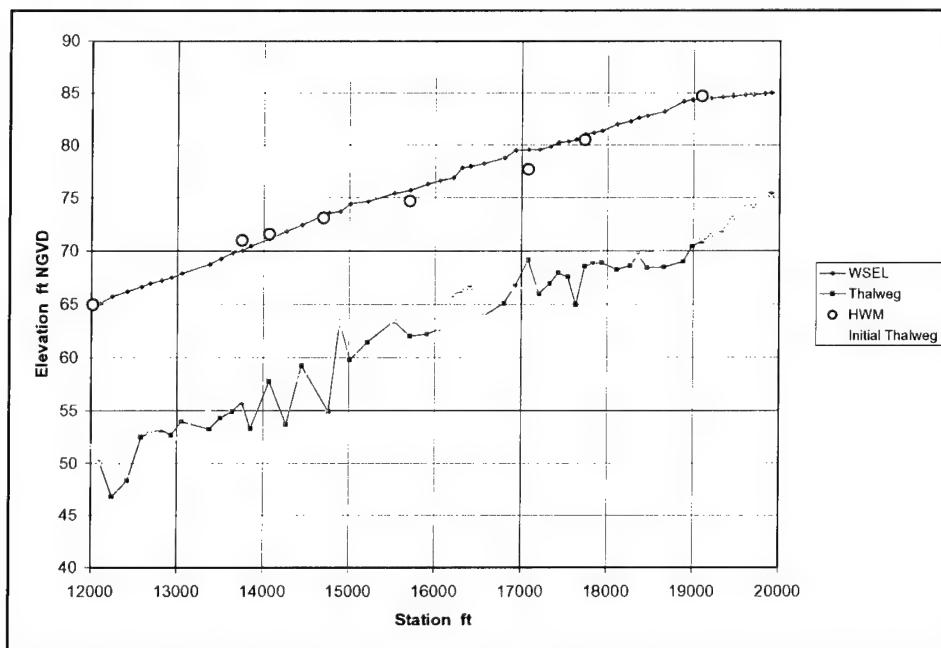| Adjusted Channel Roughness Coefficients						
	Low-Flow Discharge		Medium-Flow Discharge		Top of Bank-Flow Discharge	
Reach	cfs	n	cfs	n	cfs	n
67+90 to 114+84	100	0.030	2,500	0.065	5,000	0.075
114+84 to 120+15		0.050		0.050		0.050
120+15 to 150+06	150	0.030	4,700	0.070	9,000	0.080
150+06 to 152+10	100	0.030	3,500	0.060	7,500	0.065
152+10 to 160+52	100	0.030	3,500	0.050	7,500	0.055
160+52 to 162+05	100	0.030	3,500	0.055	7,500	0.060
162+05 to 164+00	100	0.030	3,500	0.050	7,500	0.055
164+00 to 169+26	100	0.030	3,500	0.055	7,500	0.060
169+26 to 178+30		0.043		0.043		0.043
178+30 to 188+80	100	0.030	3,500	0.060	7,500	0.065
188+80 to 199+05		0.043		0.043		0.043

Figure 7.   Water-surface elevations calculated with adjusted roughness
coefficients. Water-surface elevations estimated 10 January 1995

Hydrographs

Discharge hydrographs are simulated in the numerical model by a series of steady-state events. A hydrograph simulated by a series of steady-state events of varying durations is called a histograph. The duration of each event in the model is chosen so that changes in bed elevations from deposition or scour do not significantly change the hydraulic parameters during that event. At relatively high discharges, durations need to be short; time intervals as low as 15 min were used in this study. At low discharges, the time interval may be extended. The maximum time interval used in this study was 24 hr.

A historical hydrograph representing the period October 1992 to September 1999 was developed from gage data. The numerical histograph excluded days when the mean daily flow in the Guadalupe River at San Jose (11169000) gage was less than 50 cfs. Sediment transport is negligible below this discharge. Mean daily flows reported by the USGS for the Guadalupe River at San Jose gage were used for water years 1993-1999. Fifteen-min duration data were provided by the USGS for the Guadalupe River at San Jose gage for high-flow periods in water years 1995-1998. Mean daily flows reported by the Santa Clara Valley Water District for the Los Gatos Creek at Lincoln Avenue gage were used for water years 1993-1994 and 1999. The Santa Clara Valley Water District provided 15-min duration data for Los Gatos Creek for water years 1995-98 for high-flow periods. The 15-min duration data captures the peak discharge for many high-flow events missed using mean daily flow data due to the flashy runoff characteristics of the Guadalupe River watershed. Flow durations between 15 min and 24 hr were used in the histograph depending on the magnitude and rate of change in discharge.

The historical hydrograph developed for this study is used to interpret the river's response to change using a realistic sequence of runoff events. The runoff dates were chosen because they were the most recent and because detailed (15-min) data were available. Historical survey data were insufficient to evaluate model performance using a historical hydrograph record. Mean daily flow values for the Guadalupe River at San Jose gage are plotted in Figure 8. This figure provides information on relative significance of each year's runoff that may be used to interpret calculated bed changes in Chapters 3 and 4. Annual peak discharges are tabulated in Table 1.
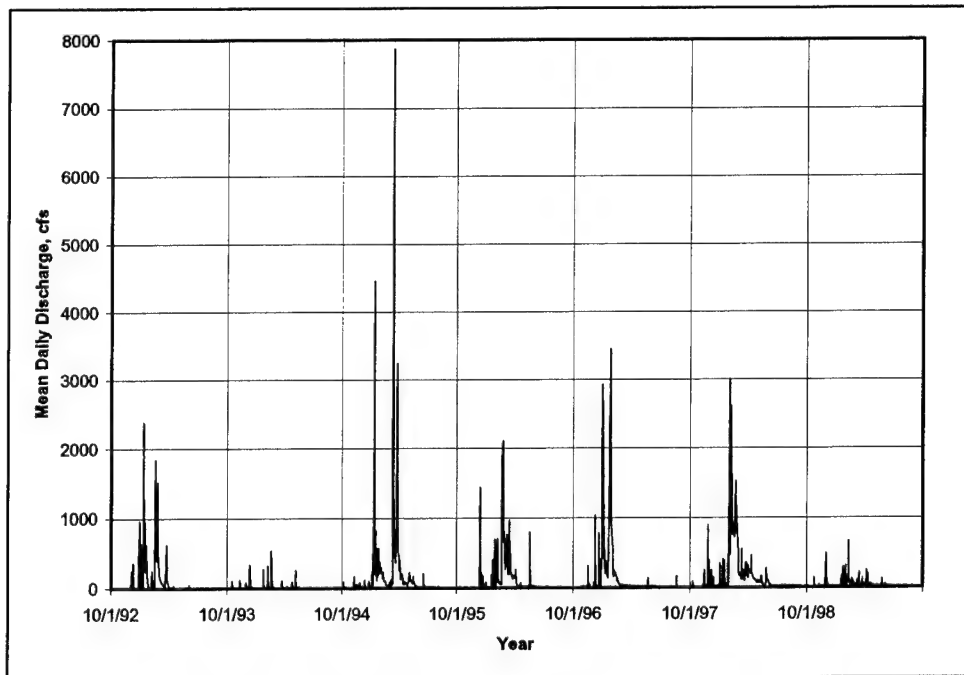
Figure 8.   Mean daily flows from Guadalupe River at San Jose USGS gage

Table 1
Guadalupe River at USGS Gage
Historical and Predicted Peak Discharges

Historical Annual Peaks	
Water Year	**cfs**
1993	4,920
1994	1,510
1995	11,000
1996	4,720
1997	5,470
1998	7,510
1999	1,300
Simulated Flood Peaks	
Percent chance exceedance	**cfs**
1	17,000
2	13,750
5	9,950
10	7,370

The numerical model was used to calculate aggradation and degradation in the project reach during the passage of the 1-, 2-, 5- and 10-percent chance exceedance floods. The flood hydrographs were determined by the U.S. Army Engineer District, San Francisco (1977) and are shown in Figure 9. Hydrologic calculations were made using the HEC-1 numerical model. This model calculates basin response to a storm event and provides hydrographs for selected points in the basin. Available reservoir storage capacities prior to the design storm were determined from historical data and some incidental reduction in flood peaks were attributed to the reservoirs. Calculated peak discharges are tabulated in Table 1.
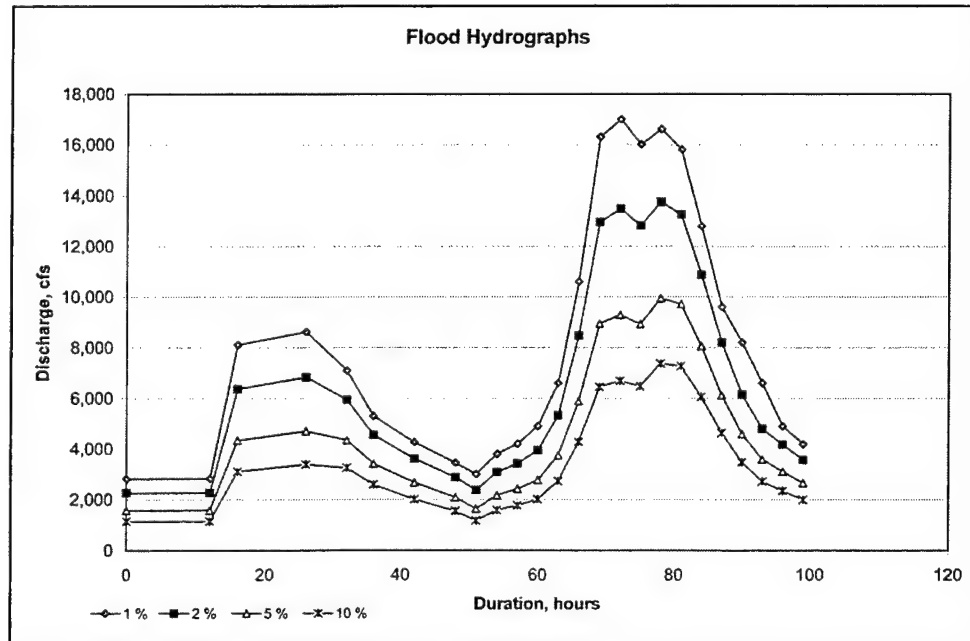

Figure 9.   Flood hydrographs at USGS gage

The U.S. Army Engineer District, Sacramento (1991) reviewed the design peak flood flows, taking into consideration the flooding and the land use changes that occurred since completion of the 1977 hydrology study. The review concluded that the 1977 hydrology properly reflects future upstream channel improvements and urbanization. The flood routings and rainfall loss rates were determined to still be valid and properly reflect prevailing conditions.

The numerical model was also used to estimate a typical annual channel response by calculating aggradation and degradation for a 12-year hydrograph determined from the historical record and dividing the calculated total by 12. The 12-year hydrograph was obtained by removing the 1995 hydrograph from the 1992-1999 historical hydrograph and then duplicating the remaining years. The rational for removing the 1995 hydrograph was that 1995 was an exceptionally wet year.

The numerical model was used to evaluate channel response using a long-term hydrograph. The hydrograph selected for the simulation started with the

12-year hydrograph previously used to estimate typical annual channel response, followed by the one-percent chance exceedance flood hydrograph, followed again by the 12-year hydrograph. The total simulation represented a 24-year period, with a 4-day one-percent chance exceedance flood hydrograph midway in the simulation.

Flow Diversion through Bypasses

The Guadalupe River Flood-Control Project includes three bypass structures. The inlet for the Woz bypass is at sta 195+93, just downstream from I-280. The Woz bypass structure is about 2,800 ft long and exits at sta 167+52, downstream from Park Avenue. The inlet for the Santa Clara bypass is at sta 153+50, just downstream from Santa Clara Street. The inlet for the St. John bypass is at sta 148+58, just upstream from St. John Street. The Santa Clara and St. John bypasses both exit at sta 124+25, just upstream from Coleman Avenue.

Flow diversion rating curves for these bypasses were determined from physical hydraulic models. The rating curve for the Woz bypass was determined from a 1:25 scale physical model study conducted between 1993 and 1996 at the Hydraulics Laboratory of the U.S. Army Engineer Waterways Experiment Station (Hite 1998). The rating curves for the Santa Clara and St. John bypasses were determined from a 1:25 scale physical hydraulic model study conducted between 2000 and 2001 at Utah State University (Rahmeyer 2001). The flow diversion rating curves used in this study are shown in Figure 10.
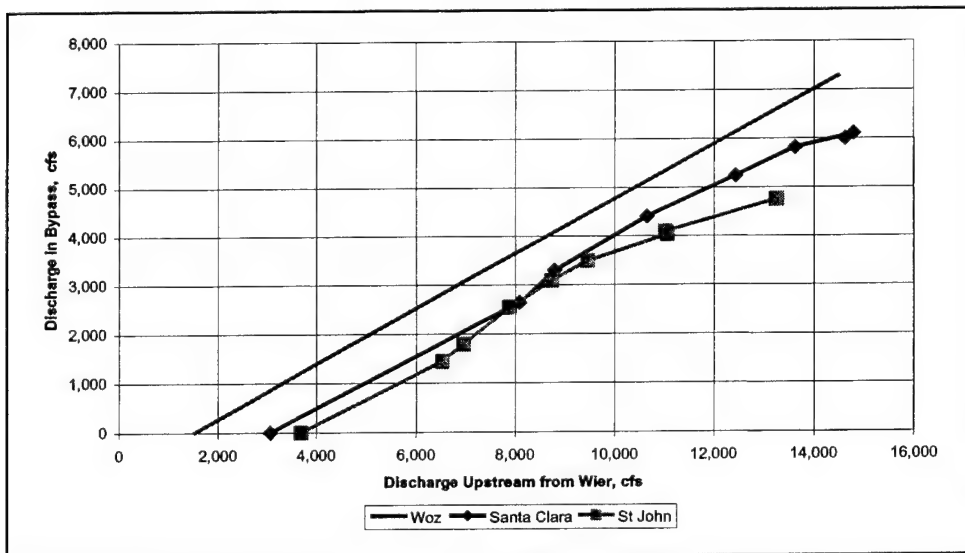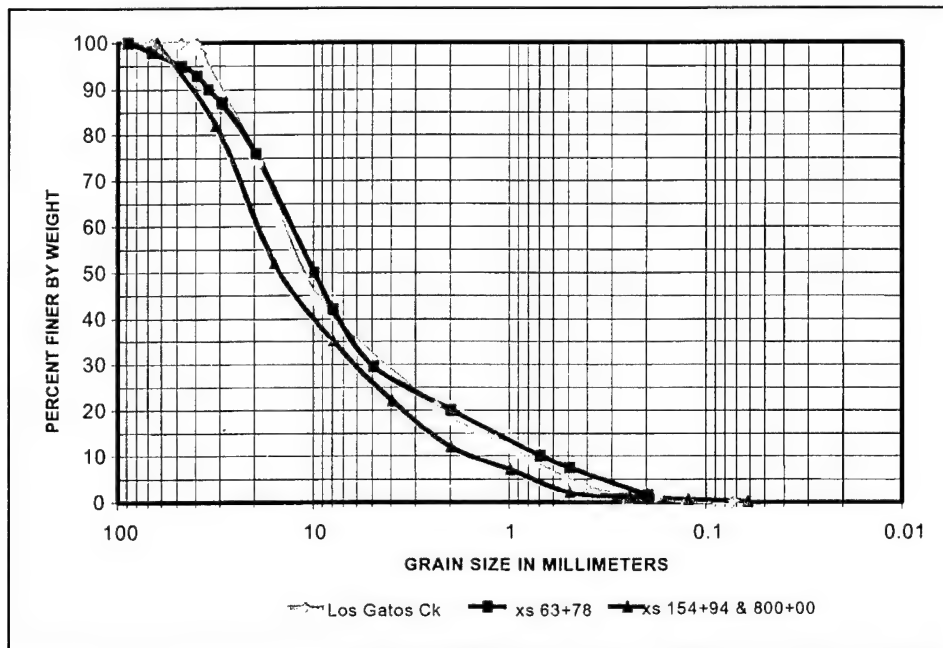

Figure 10. Bypass flow diversion rating curves from physcial hydraulic model studies

Bed Material

Initial bed-material gradations for this study are based on those assigned in the 2000 SPK HEC-6 sediment model. These gradations were based on samples collected in 1987 and 1988 and reported by WET (1991). Three bed-material gradations were used in the numerical model. Initial model bed-material gradations are shown in Figure 11. The bed gradation at the downstream end of the model is labeled 63+78. The next gradation is at sta 154+94. Between these stations the initial model bed-material gradations are interpolated. A constant initial bed material gradation is assigned between sta 154+94 and the upstream model boundary. A bed-material sample collected on Los Gatos Creek just upstream from its confluence with the Guadalupe River was used for all Los Gatos Creek cross sections.

Figure 11. Bed-material gradations used in numerical model study. From 2000 SPK HEC-6 model and WET samples collected in 1987 and 1988

Bed-material samples were collected from several alluvial deposits in the study reach during a March 2001 field reconnaissance. The bed gradations determined from the March 2001 data were found to be consistent throughout the Guadalupe River study reach and in Los Gatos Creek. Bed gradations are shown in Figure 12. The 2001 data served to confirm previously adopted bed-material gradations and the previously adopted bed-material gradations were retained in the numerical model for this study.
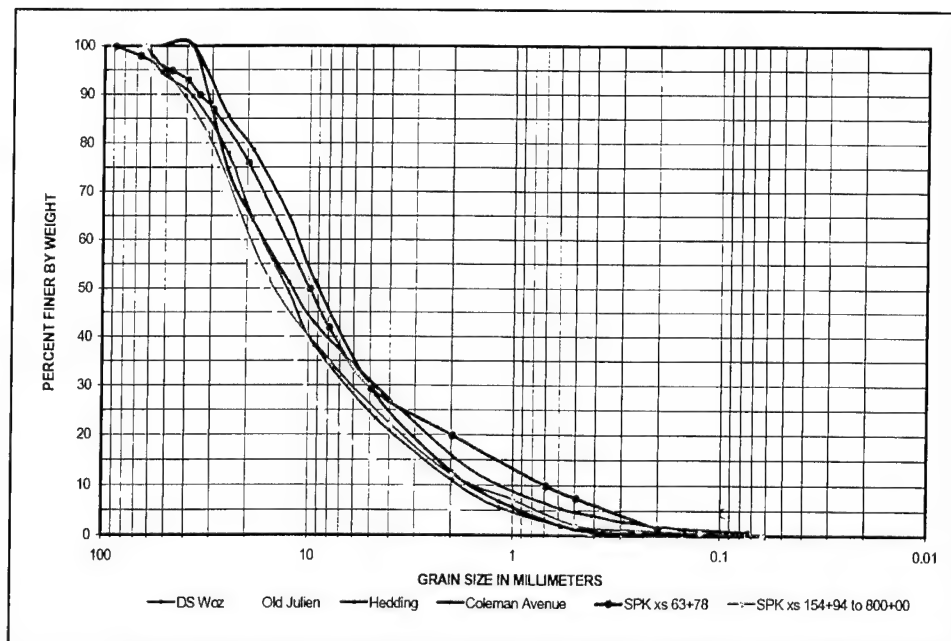
Figure 12. Bed samples collected in March 2001 compared to previously reported data

Based on limited field observations, it appeared that bed erosion will be retarded by a nonalluvial bed in many locations. These include some bridge crossings where the invert is paved, the USGS weir, the encased pipeline under Old Julian Street, and several dumped rock or rubble grade control structures. In the numerical model the maximum bed sediment reservoir thickness was set at 5 ft where it appeared that there was an alluvial surface layer. In locations where the bed was stabilized by invert control the bed sediment reservoir was set equal to zero. The locations where invert controls were identified by field observations or construction plans are listed in Table 2.

Sediment Transport Function

The sediment transport function chosen by the Sacramento District for their numerical model study was the Toffaleti-Meyer-Peter Muller function. NHC also used this function in sediment studies on the Guadalupe River. With this function, bed load is calculated using the Toffaleti (1968) and the Meyer-Peter Muller (1948) methods and the larger of the two is used. Suspended load is then calculated using the Toffaleti method. The Toffaleti-Meyer-Peter Muller function is capable of calculating both sand and gravel transport rates for the size classes found in the bed material of the Guadalupe River over the range of discharges used in this study. For consistency, this function was retained for this study.

Table 2
Locations Where Bed Sediment Reservoir Set Equal to Zero
Existing Conditions

Cross Section Station - ft	Feature
63+78	Invert control at I-880 bridge
64+94	Invert control at I-880 bridge
65+90	Invert control at I-880 bridge
117+09	Grade control structures
118+37	Grade control structures
120+15	Invert control at Coleman Avenue
137+50	Encased pipeline at Old Julian Street
148+87	USGS gage
160+52	Dumped rubble at Highway 87
162+05	Dumped rubble at Highway 87
163+00	Dumped rubble at Highway 87
164+00	Dumped rubble at Highway 87
165+58	Dumped rubble at Highway 87
169+26	Invert control at Park Avenue
170+79	Invert control at Park Avenue
194+24	Dumped rubble at I-280
195+29	Dumped rubble at I-280
196+27	Dumped rubble at I-280
197+29	Dumped rubble at I-280
198+53	Dumped rubble at I-280

Sediment Inflow

Bed-material load

The bed-material load in the Guadalupe River is unknown. There are no sediment measurements of the coarser fraction of the bed-material load. There are no extensive fully-alluvial reaches where sediment transport can be calculated with a high degree of confidence. Of all the numerical model inputs, the bed-material load has the highest degree of uncertainty associated with it. For this reason, the bed-material load was estimated using the best engineering techniques available and then was adjusted so that the numerical model would simulate reasonable responses with the existing channel geometry.

The Guadalupe River between I-880 and I-280 and immediately upstream of I-280 is an incising under-fit stream. During the field reconnaissance an

appropriate fully-alluvial supply reach was not identified upstream from the study reach. A fully-alluvial reach is one in which the bed gradation extends across the full width of the channel and for a significant distance upstream and downstream. The bed material must be representative of a bed that would actively exchange with the water column at higher flows. Because there are no measurements of bed-material load in the Guadalupe River, a fully-alluvial supply reach is needed in order to calculate the sediment inflow. This calculation requires a representative bed-material gradation and average hydraulic parameters for a uniform reach. There are many localized alluvial deposits in the channel that make it possible to determine the gradation of the bed material, but the observed deposits were not extensive enough to assume that sediment transport could be calculated for a range of discharges using average hydraulic parameters in a given reach.

A fully-alluvial reach was identified upstream from Coleman Avenue during the March 2001 field reconnaissance. A bed-material gradation was collected from this reach at about sta 123+00 and is shown in Figure 12, labeled "Coleman Avenue." The bed sediment reservoir was found to be greater than 2 ft thick. Hydraulic parameters for the sediment-rating curve calculation were determined from a HEC-2 backwater calculation using geometry from the HEC-6W numerical model and are tabulated below. For the reach downstream from Coleman Avenue the geometry came from the file EC100.DAT supplied by the Sacramento District. Geometry upstream from Coleman came from the file G7XABC13.DAT, also supplied by the Sacramento District. The later file is based on 1987 survey data modified to account for the fact that the survey did not necessarily provide a complete definition of the underwater portion of the channel. Calculated bed-material sediment transport is shown in Figure 13.

Average Effective Hydraulic Parameters Calculated Upstream from Coleman Avenue sta 120+32 – 126+85

| Total Discharge cfs	Channel Discharge cfs	Channel Velocity fps	Effective Depth ft	Effective Width ft	Energy Slope
10	10	0.21	1.72	27.2	0.0000099
50	50	0.63	1.89	42.2	0.0000716
100	100	1.05	2.12	44.9	0.000175
200	199	1.66	2.37	50.6	0.000408
500	500	2.72	3.18	57.8	0.000909
1000	1,000	3.61	4.19	66.1	0.00141
2000	2,003	4.73	5.55	76.3	0.00221
5000	4,999	6.32	7.8	101.4	0.00411
10000	10,000	7.73	10.13	127.7	0.00576
15000	14,974	8.75	12.18	140.5	0.0065
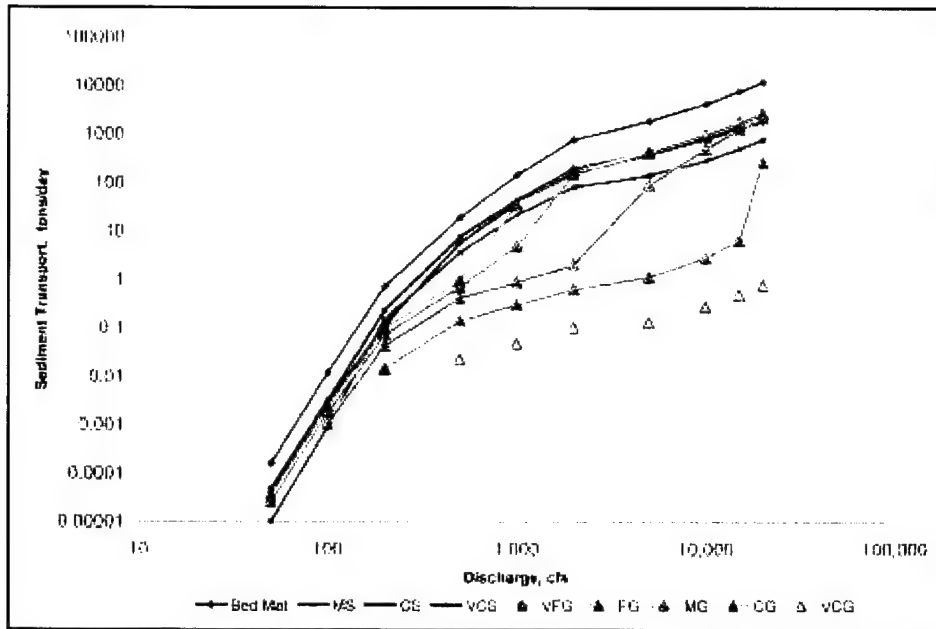
Figure 13. Calculated bed-material sediment transport upstream Coleman
Avenue using Toffaleti-Meyer-Peter and Muller

The sediment-transport rating curve calculated for the fully-alluvial reach was
adjusted and translocated to the upstream model boundaries on both Los Gatos
Creek and the Guadalupe River. The sediment rating curve adjustment for each
branch was determined by multiplying both the discharge and sediment load by
the fraction of total runoff from each branch. Total accumulated runoff between
October 1992 and September 1999 was used to determine the runoff fraction. It
was determined that 44 percent of the runoff came from Los Gatos Creek and 56
percent from the Guadalupe River. It is expected that the actual sediment transport
inflow would be less than predicted by these curves, because the system was
observed to be incising and because there did not appear to be a bed sediment
supply available to sustain sediment transport. These sediment inflow curves
were further adjusted for use in the numerical model study during the
circumstantiation phase of the numerical model study reported in Chapter 3.

Finer sand load

The USGS collected 99 suspended sediment samples at the Guadalupe River
at San Jose Gage 11169000 between 1957 and 1962. Particle-size distributions
were determined for 18 of these samples. The sediment sizes collected by the
USGS were not found to be present in the bed material of the Guadalupe River in
significant quantities. According to Einstein (1950) these sediment sizes should
therefore be considered wash load. Wash load passes through the reach and is not
a major factor in channel aggradation or degradation. The sand sizes of the wash
load were included in the numerical model, because they could become part of the
bed-material load in the lower reaches of the river where flow spreads onto the
floodplain and channel velocities decrease.

A regression curve for total measured sediment load was determined from the 99 measurements. This curve is shown in Figure 14. The data were collected for a range of discharges between about 2 and 3,000 cfs. The curve was extrapolated for higher discharges. The unbiased regression curve was used to determine average sediment load. The unbiased curve accounts for averaging errors inherent to regression analysis using logarithmic values. Note that r^2 is only 0.4, indicating poor correlation between discharge and concentration and thus a high degree of uncertainty associated with the regression curve. The importance of using the unbiased regression curve is apparent when the sediment data are plotted in Cartesian coordinates as shown in Figure 15.

Percentages for each sand size class were determined from the 18 size class determinations. The data ranged between 10 and 2000 cfs. Regression curves were developed for very-fine, fine and medium sand size classes and for the total measured concentration as shown in Figure 16. Insufficient data were available to develop a curve for coarse sand. The percentage of the total measured concentration associated with each sand size class was then determined. Percentages calculated at 2,000 cfs were used for higher discharges; the regression curves were not extrapolated beyond 2,000 cfs. Sediment concentrations for the measured sand load are shown in Table 3. The total sand load is also given. Note that the nature of regression analysis does not insure that the sum of the parts will equal the total.

Unbiased
$C\ tot = 22.067Q^{0.6308}$

$C\ tot = 10.029Q^{0.6308}$
$R^2 = 0.3983$
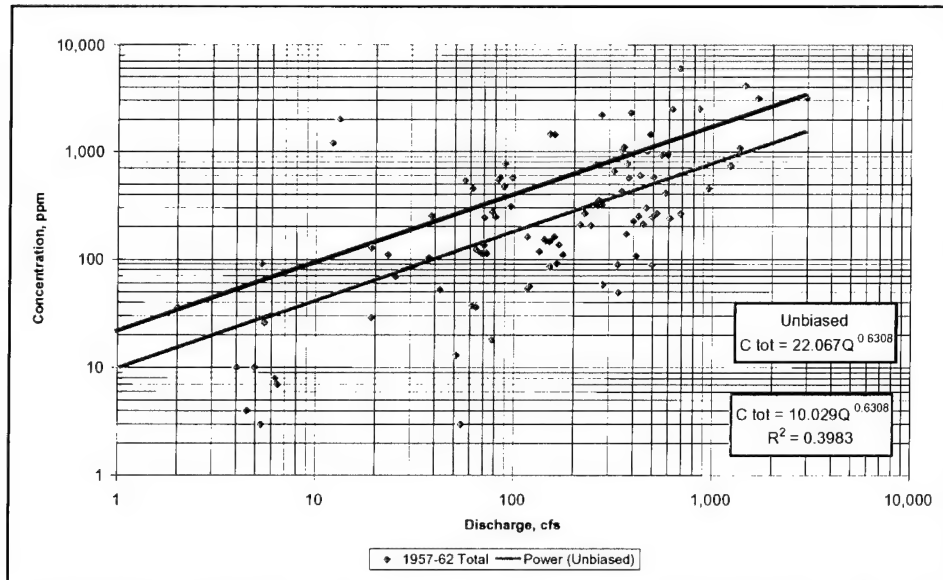
♦ 1957-62 Total ——Power (Unbiased)

Figure 14. Measured suspended sediment concentration, Guadalupe River at San Jose, 1957-62
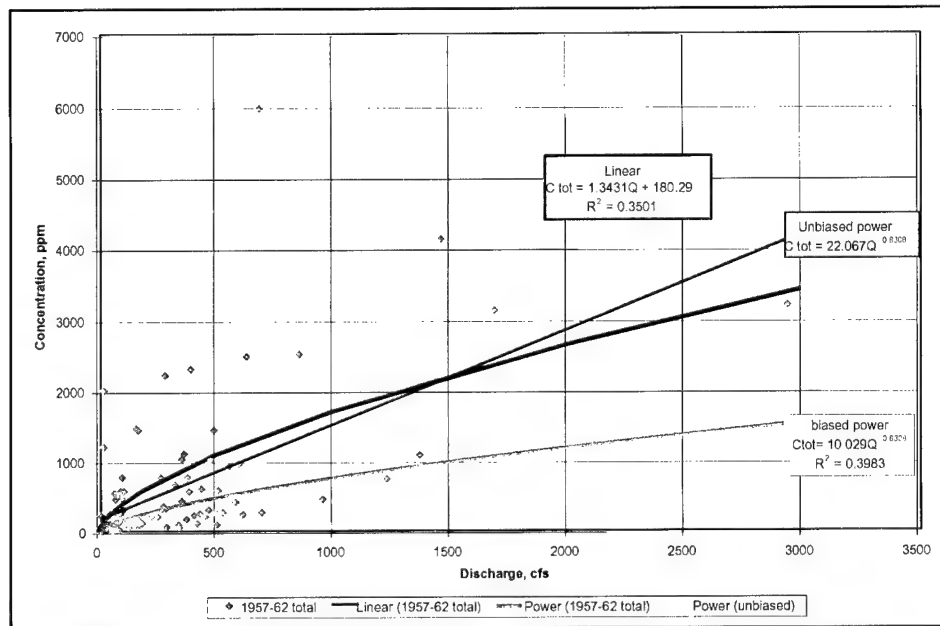
Figure 15. Measured suspended sediment concentration on Cartesian plot, Guadalupe River at San Jose, 1957-62
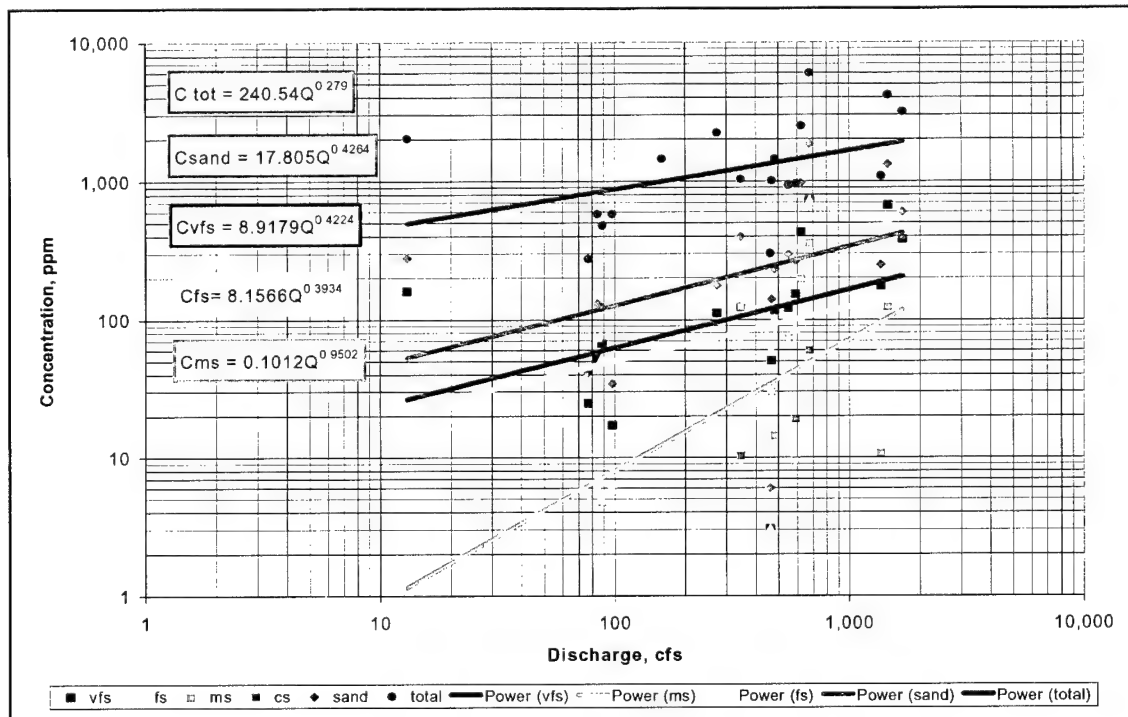

Figure 16. Measured suspended sediment sand size class distributions, Guadalupe River at San Jose, 1957-62

Table 3
Calculated Sand Inflow from Measurements

Discharge cfs	Total mg/L	Sand mg/L	Very Fine Sand		Fine Sand		Medium Sand	
			mg/L	Fraction	mg/L	Fraction	mg/L	Fraction
10	457	48	24	0.052	20	0.044	1	0.002
20	555	64	32	0.057	27	0.048	2	0.003
50	716	94	47	0.065	38	0.053	4	0.006
80	817	115	57	0.069	46	0.056	7	0.008
100	869	127	62	0.072	50	0.057	8	0.009
200	1,055	170	84	0.079	66	0.062	16	0.015
500	1,362	252	123	0.090	94	0.069	37	0.027
800	1,553	308	150	0.097	113	0.073	58	0.037
1000	1,653	339	165	0.100	124	0.075	72	0.043
2000	2,005	455	221	0.110	162	0.081	139	0.069

Sediment Diversion Concentrations in Bypasses

Sediment diversion concentrations into the bypasses are specified as boundary conditions in the numerical model. The ratio of diverted sediment concentration to the main channel sediment concentration upstream from the diversion is specified for each sediment size class. Inlet weirs at each of the bypass structures are designed to draw flow from the upper portion of the water column in the main channel. Coarse sediment concentrations are higher at the bottom of the water column, while fine sediment is more evenly distributed in the water column. Thus, the concentration diversion ratios will be higher for finer sediment than for coarser sediment. If the vertical velocity distribution and the vertical concentration distributions for each size class are known, then the diversion ratios can be calculated from the following equation:

$$diversion\ ratio_i = \frac{\int_{y=h}^{y=D} C_{iy}\ u_y\ dy}{\int_{y=a}^{y=D} C_{iy}\ u_y\ dy} \tag{2}$$

where:

C_i = concentration of sediment size class i

D = depth of flow in the main channel

h = weir height

a = reference height near the stream bed – taken to be zero for these calculations

u = velocity

Using the simplifying assumption of a uniform velocity distribution and the Rouse (1937) equation for calculating sediment concentration, the following equation is derived by substitution.

$$diversion\ ratio_i = \frac{\displaystyle\int_{y=h}^{y=D} C_{ia} \left[\frac{D-y}{y} \frac{a}{D-a} \right]^Z \bar{u}\ dy}{\displaystyle\int_{y=a}^{y=D} C_{ia} \left[\frac{D-y}{y} \frac{a}{D-a} \right]^Z \bar{u}\ dy} \tag{3}$$

where:

C_{ia} = concentration at the reference elevation

u = average channel velocity

and

$$z = \frac{\omega}{\beta k\ u_*}$$

where

$?$ = particle fall velocity

β = ratio of sediment and momentum exchange coefficients – taken to be 1.0

k = Von Karman constant – taken to be 0.4

u_* = shear velocity

Removing the constant terms leaves Equation 4, which can be solved using numerical integration. Hydraulic terms for this equation can be determined from a backwater analysis for a range of discharges. Other terms are known.

$$diversion\ ratio_i = \frac{\displaystyle\int_{y=h}^{y=D} \left[\frac{D-y}{y} \right]^Z dy}{\displaystyle\int_{y=a}^{y=D} \left[\frac{D-y}{y} \right]^Z dy} \tag{4}$$

Compound weirs were designed for the Santa Clara and St. John Inlets. The purpose of the compound weirs was to reduce sediment inflow into the bypass culverts at high flow. Insufficient data were available to determine the flow distribution across the weirs, so the lower weir crest elevation was used to determine sediment diversion ratios for the numerical model study. This

assumption will result in more sediment diversion and thus greater channel instability downstream, which is the conservative assumption for this study. Figures 17 – 19 show the sediment diversion rating curves used in this study. Sediment concentrations of bed-material sediment in the bypass structures are significantly less than in the main channel. Very little gravel is diverted into the bypasses even at very high discharges. In the numerical model, all sediment diverted into the bypasses is assumed to be transported through the structures without deposition. A special modification was made to the HEC-6W numerical code to accommodate this process.
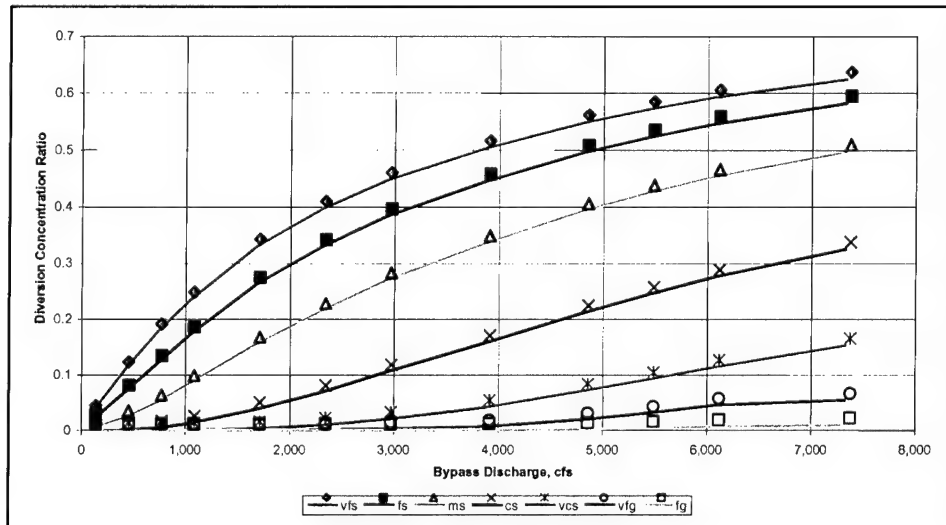
Figure 17. Calculated diversion concentration ratios for Woz bypass
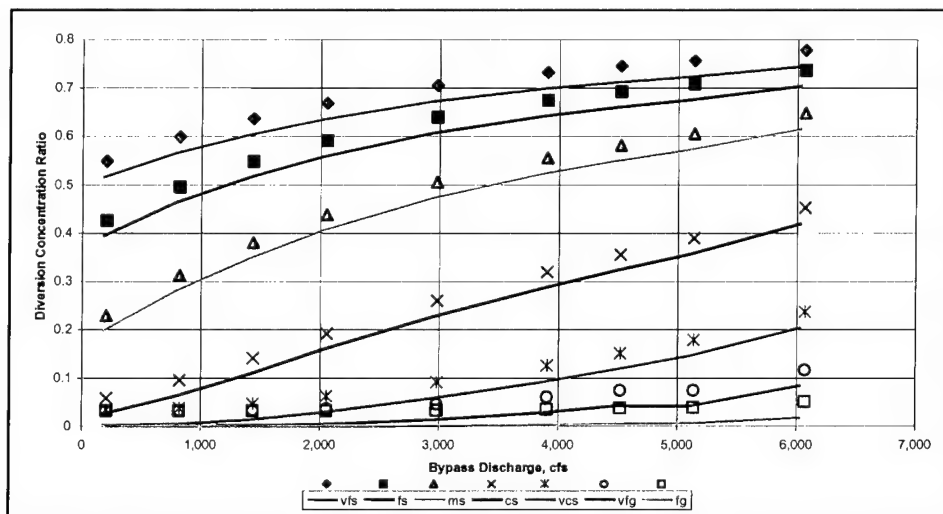
Figure 18. Calculated diversion concentration ratios for Santa Clara bypass
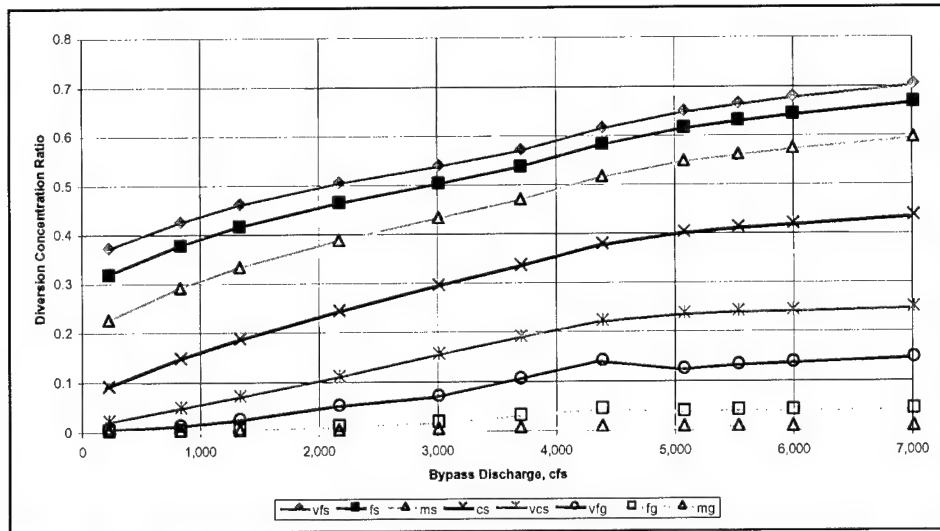
Figure 19. Calculated diversion concentration ratios for St. John bypass

3   Model Adjustment and Sensitivity

Model Adjustment to Existing Conditions

The numerical model adjusts initial cross-section geometry and bed composition to the calculated hydraulic parameters and sediment transport rates. It is expected that some adjustment in geometry will occur early in the simulation due to inaccuracies associated with the survey data used to develop the numerical model. Adjustments should also be expected in cross sections where the numerical model's assumption of one-dimensional flow does not apply. An example would be a cross section downstream from a weir where a local scour hole has developed. In addition, the initial bed gradation provided for each cross section in the model does not include an armor layer. The model's bed sorting algorithm calculates an armor layer as the simulation proceeds, maintaining sediment continuity for each size class. The bed-sorting algorithm balances sediment supply from upstream and from the bed sediment reservoir with the sediment transport capacity. Sediment transport capacity is a function of the composition of the surface layer. If sediment transport capacity at a cross section is greater than the sediment supply the model will scour the bed, sorting out the finer particles, coarsening the bed, which in turn reduces the sediment transport capacity. This process continues until the sediment transport capacity is in balance with the sediment supply.

Sediment Inflow Adjustments

The sediment inflow has a high level of uncertainty and was chosen as the primary adjustment parameter for the numerical model study. Sediment inflow was adjusted so that the bed response predicted by the numerical model over a 7-year period appeared to be reasonable based on field observations.

Using an iterative procedure, bed changes were calculated with the numerical model for a 7-year runoff period. Measured discharges from the Guadalupe River and Los Gatos Creek between October 1992 and September 1999 were used in the

model. The simulation was not intended to be a historical simulation of bed changes, as the initial geometry did not represent conditions in October 1992.

Field evidence indicates that the Guadalupe River is incising. During field reconnaissance for this study, recent incision on the order of 2 ft or more was observed between the USGS gage at sta 148+87 and the railroad bridge at sta 130+00. Incision of the same order of magnitude was observed between Coleman Avenue at sta 120+00 and I-880 at sta 64+00. The existence of many dumped rubble sills and exposed pipelines between the USGS gage and the upstream model boundary is evidence of historical degradation and continued degradation potential.

At the beginning of the adjustment phase of the study, sediment inflow was based on calculated sediment transport capacity just upstream from Coleman Avenue and on sediment measurements at the USGS gage. Sediment measurements were used to determine sediment inflow for size classes between 0.0625 and 0.5 mm. Measured concentrations of medium sand were greater than calculated concentrations of medium sand, so the measured data were used. Calculated sediment concentrations were used for size classes between 0.50 and 64 mm. The development of the initial sediment transport rating curves used at the beginning of the adjustment study was discussed in Chapter 2.

Sediment inflow adjustments consisted of reducing the sediment inflow at the upstream model boundary on the Guadalupe River and limiting the depth of the bed-sediment reservoir in the supply reach upstream from I-280. Sediment inflows of gravel size classes were reduced to prevent buildup of sediment at the upstream boundary. Then sediment inflows of all size classes were reduced by 75 percent on the Guadalupe River and 50 percent on Los Gatos Creek. The criterion for adjustment on the Guadalupe River was reducing deposition between Woz Way and the I-280 bridges to an insignificant quantity to be consistent with observed conditions. The criterion for Los Gatos Creek was reasonable degradation downstream from the Los Gatos confluence.

Calculated volume changes with the adjusted sediment inflow for each reach in the numerical model after the 7-year simulation are shown in Figure 20. These reaches have different reach lengths so that this figure does not provide a visually accurate view of the distribution of aggradation and degradation. Accumulated sediment deposition calculated from the downstream model boundary after the 7-year simulation is shown in Figure 21. The distribution of sediment degradation and aggradation can be determined from this figure. In the figure a negative slope indicates a degrading reach and a positive slope indicates an aggrading reach. Calculated changes in channel thalweg elevations are shown in Figure 22.

Calculated bed response shown in Figures 20 through 22 indicate a slight aggradation trend between sta 190+00 and 200+00. This is the consequence of channel widening that accompanied the construction of the Woz Way bypass inlet structure. The model shows general degradation downstream from sta 190+00 to Park Avenue (sta 170+00). Calculated deposition at Park Avenue is due to channel widening. Calculated degradation of 0.5 to 1.5 ft downstream
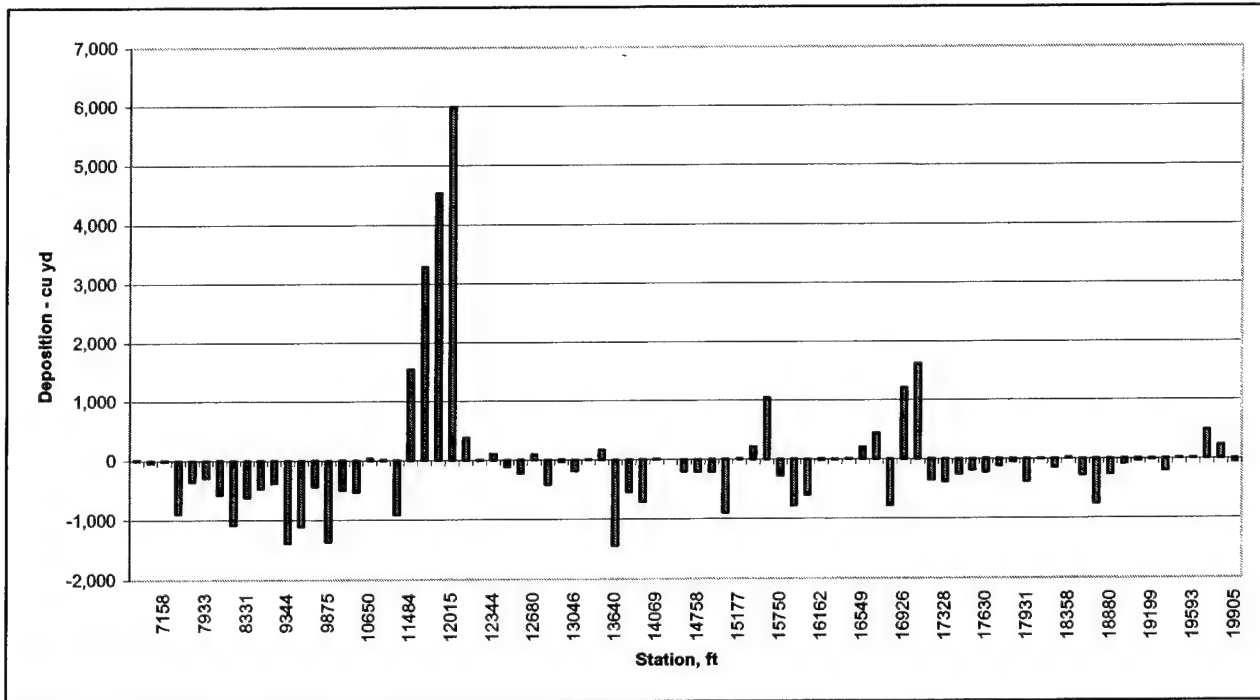
Figure 20.   Calculated sediment deposition by reach after 7-year hydrograph with existing conditions
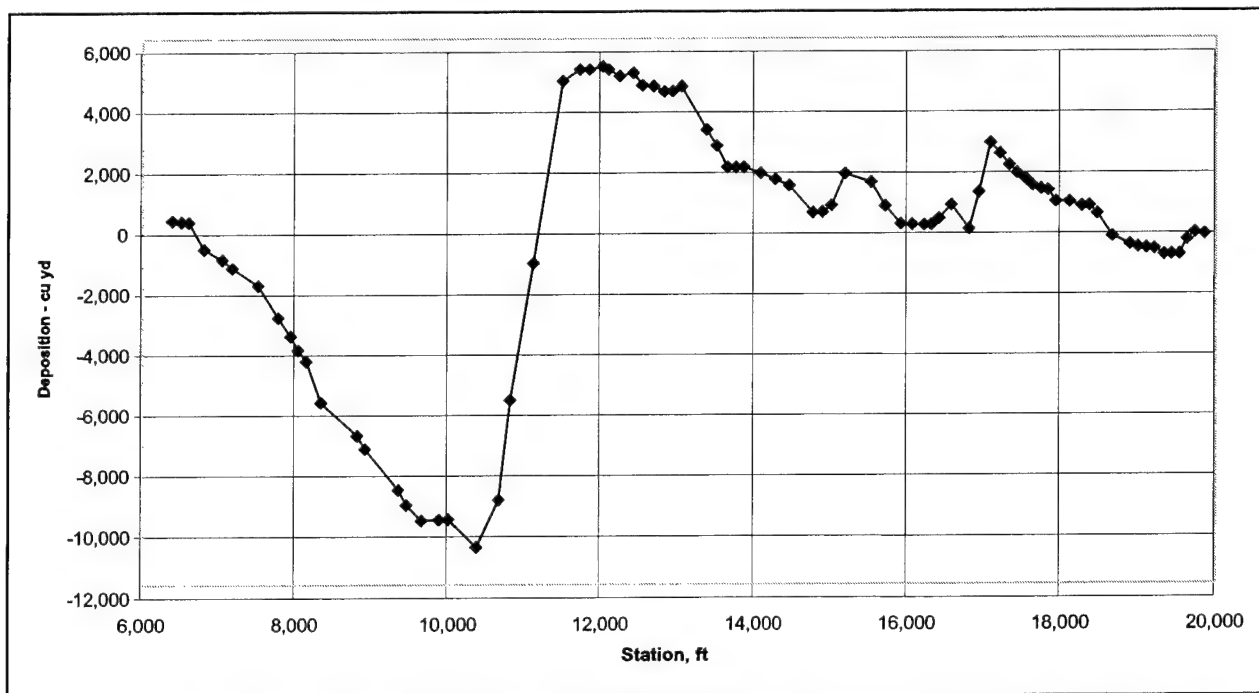

Figure 21.   Calculated sediment deposition accumulated from the downstream boundary after 7-year simulation with existing conditions
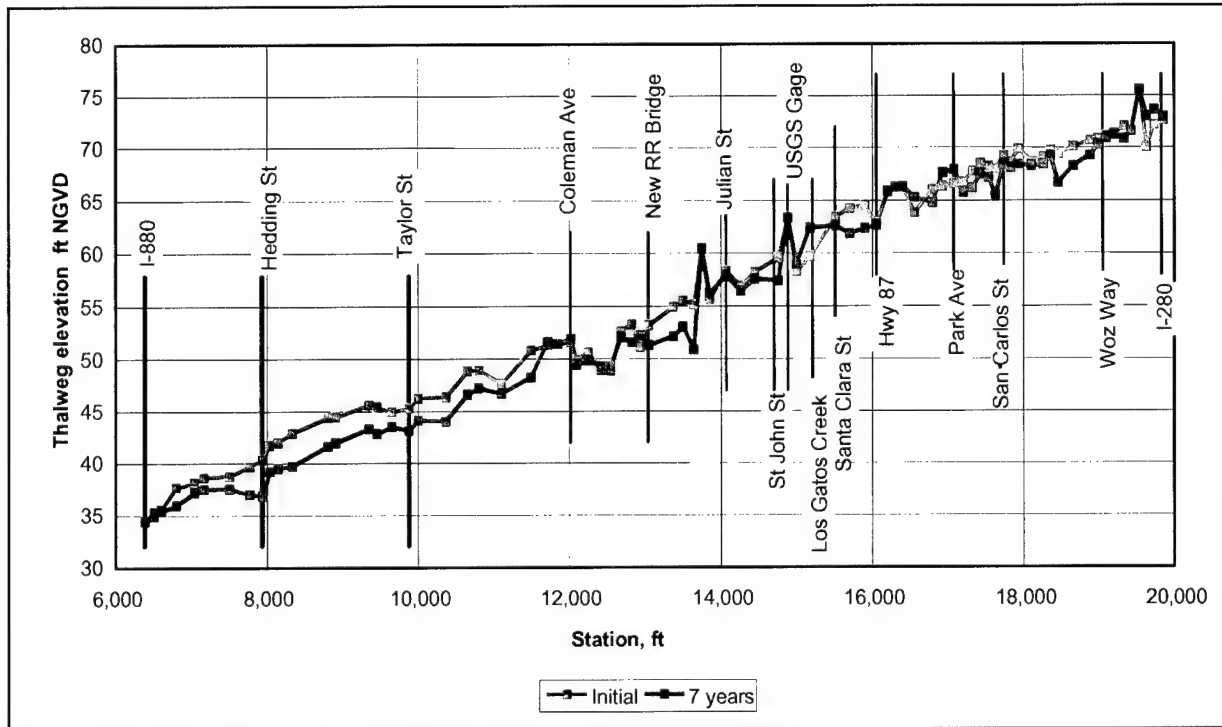
Figure 22.   Calculated thalweg elevations after 7-year simulation

from the USGS gage (sta 148+87) to the railroad bridges (sta 131+00) is con-
sistent with field observations. Considerable deposition was calculated down-
stream from Coleman Avenue in the numerical model. This deposition occurred
on the overbank during high flood events. Figure 23 shows the calculated bed
elevations at sta 114+84 at the end of 3 years (1995) and at the end of the 7-year
simulation (1999). Note that the channel bed has degraded during the simulation.
Degradation occurs at medium to low flows when the discharge is contained in the
channel. This trend of deposition on the floodplain and degradation in the chan-
nel is consistent with field observations made by engineers from the Sacramento
District after the 1997 flood when the channel and overbank geometry simulated
in the numerical model had been constructed. The observed degradation trend
downstream to the I-880 bridge was simulated satisfactorily by the numerical
model.

The variation of deposition with annual hydrograph is shown in Figure 24.
During the first year (1993) there was significant degradation trend in the reach
between I-880 and sta 105+00. This is partially due to adjustment of the initial
geometry and surface bed gradations in the model. Water years 1994 and 1999
were low runoff years and the model calculated no significant bed changes in the
study reach. Water year 1995 was a significant flood year and considerable
degradation occurred in the reach between Coleman Avenue and Los Gatos Creek
and downstream from sta 105+00. Aggradation occurred on the overbank
downstream from Coleman Avenue to sta 105+00. In water year 1996, which was
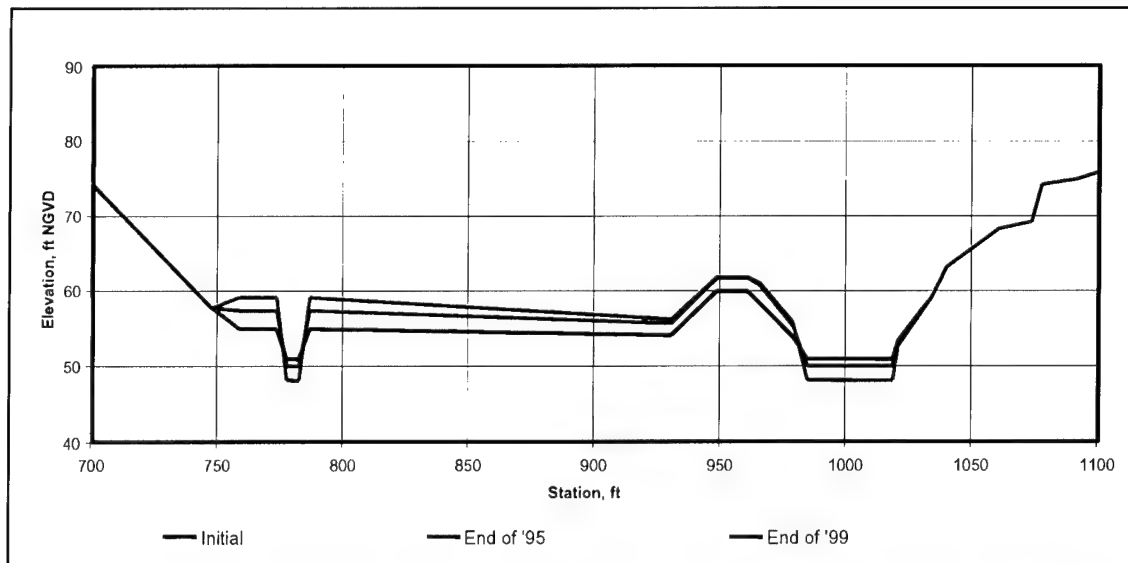a relatively low runoff year, some aggradation and degradation trends were

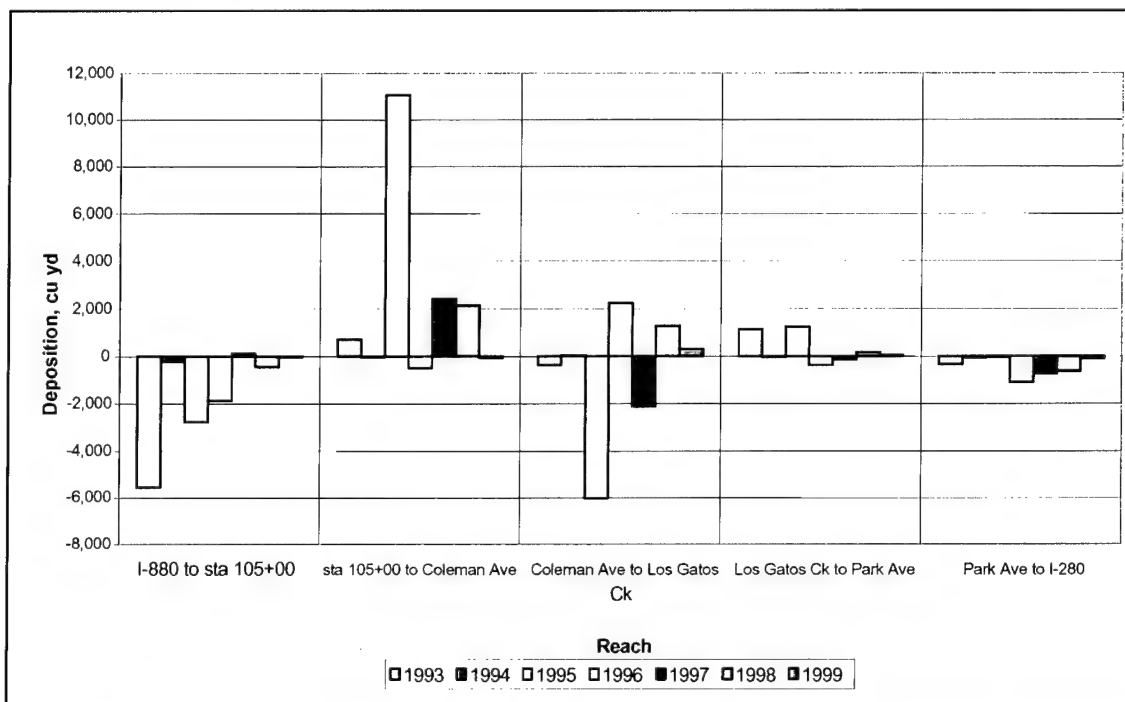Figure 23. Calculated sediment deposition at cross section 114+84 at end of water years 1995 and 1999

Figure 24. Calculated sediment deposition for each year during the 7-year simulation with existing conditions

reversed. In the reach between Coleman Avenue and Los Gatos Creek aggradation replaced some of the bed material scoured during the previous year. In 1996, discharges were not high enough to induce deposition on the floodplain downstream from Coleman and a net degradation trend was calculated. A general degradation trend continued downstream from sta 105+00. This figure demonstrates that the aggradation and degradation trends in the study reach are not necessarily consistent and vary depending on antecedent flow from previous years.

Calculated average bed changes during each year are shown in Figures 25 and 26. The most significant changes occur in 1993 and 1995. The first year of the numerical simulation was 1993, and some of the bed changes may be attributed to surface layer and geometry adjustments in the model. A major runoff year was 1995. After 1995, bed changes are generally small in comparison to the initial (1993) response and the flood (1995) response. Exceptions are upstream from Coleman Avenue and downstream from Julian Street where the bed changes move up and down in response to the magnitude of the annual hydrograph, and the model continues to predict degradation after 1995 downstream from Coleman. The calculated aggradation downstream from Park Avenue and the degradation upstream seems to have stabilized after 1995.
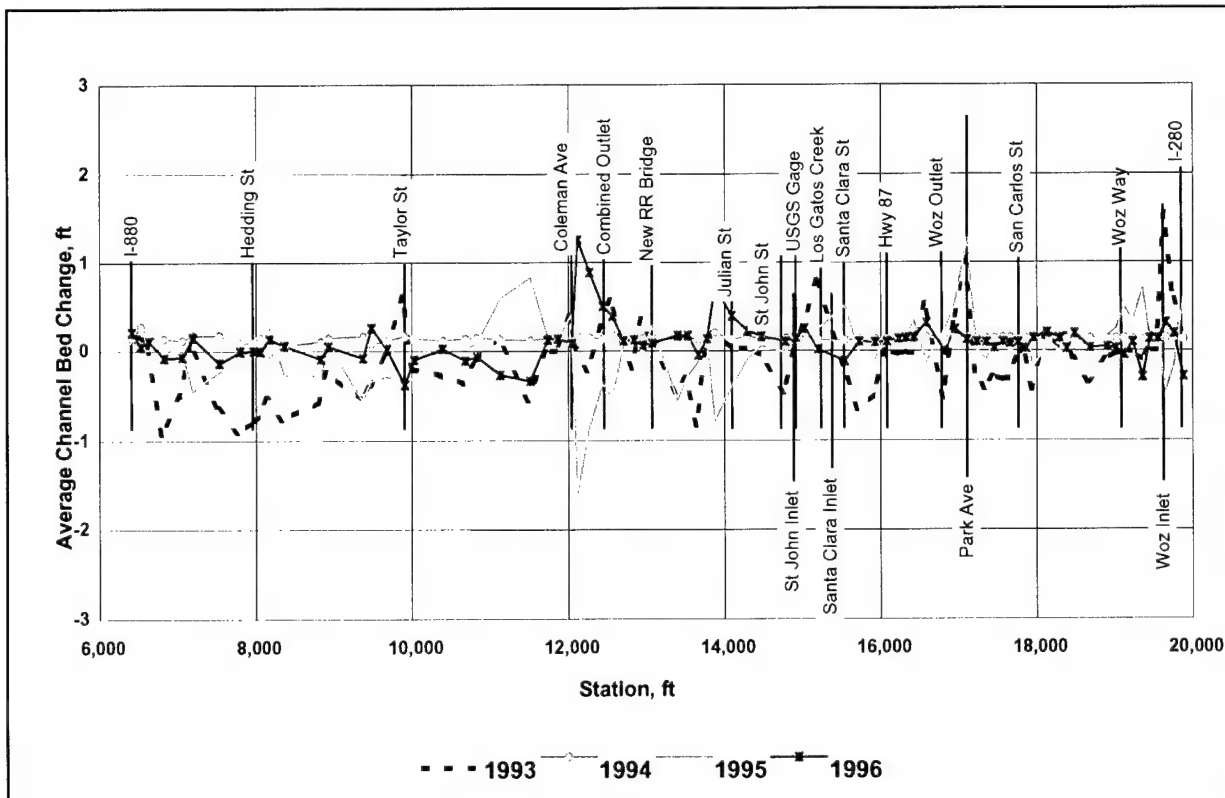

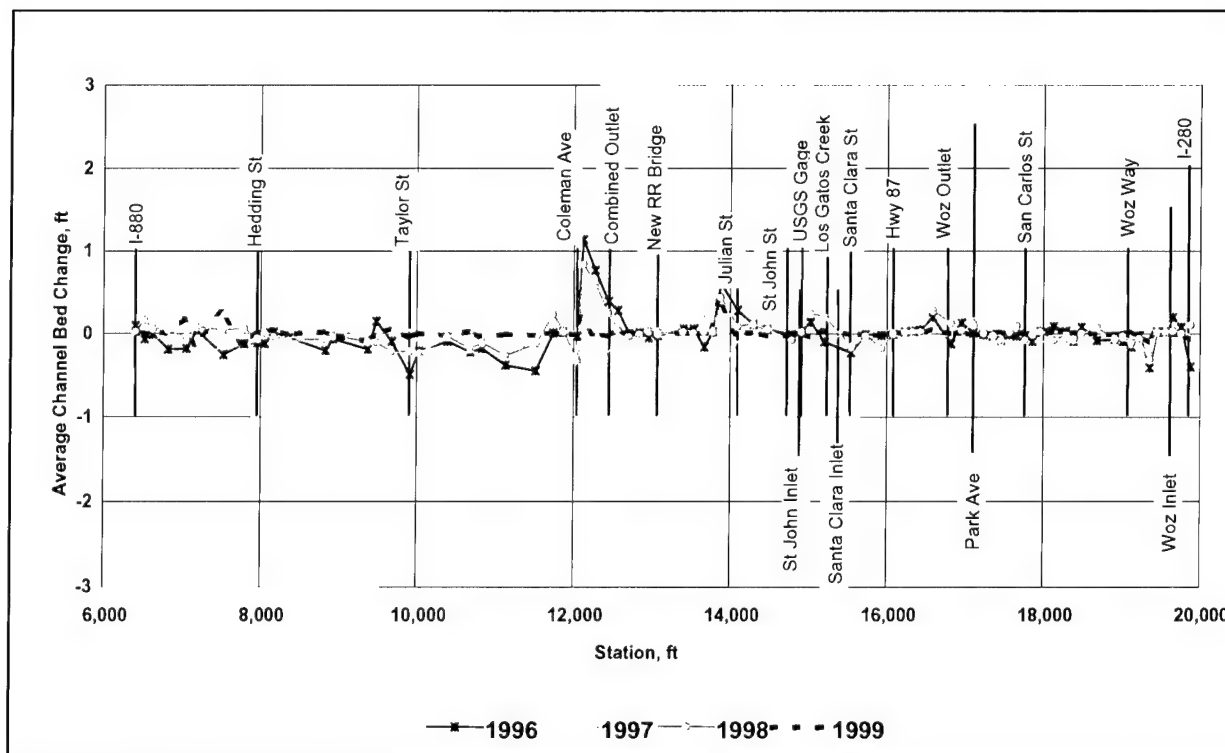Figure 25. Calculated bed change during each calendar year 1993-96

Figure 26. Calculated bed change during each calendar year, 1996-99

Response to Flood Event

Predicted bed response during the passage of a flood was evaluated in the numerical model using the 9-15 March 1995 flood event. Bed changes accumulated from the beginning of the flood hydrograph were extracted from the October 1992-September 1999 historical hydrograph during the rising and falling limbs. Average bed changes at the peak discharge and at three points on the rising limb of the hydrograph are shown in Figure 27. This figure demonstrates that during a flood event, deposition and scour trends are different than the long-term trends. Degradation in some reaches induces aggradation in downstream reaches. Degradation is especially active upstream from Coleman Avenue and aggradation is especially active downstream from Coleman Avenue. Figure 28 shows average channel bed change at the peak discharge and at three points on the falling limb of the hydrograph. This figure shows that some of the scour and deposition that occurred during the rising limb is reversed on the falling limb, especially upstream and downstream from Coleman Avenue.
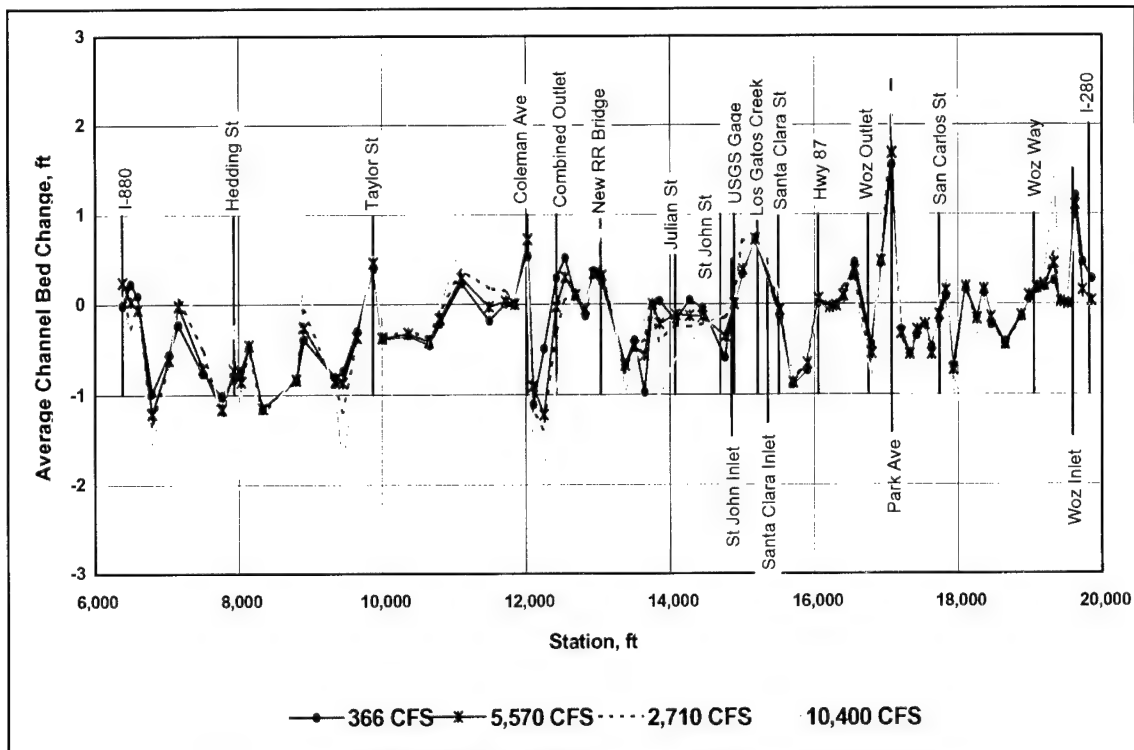
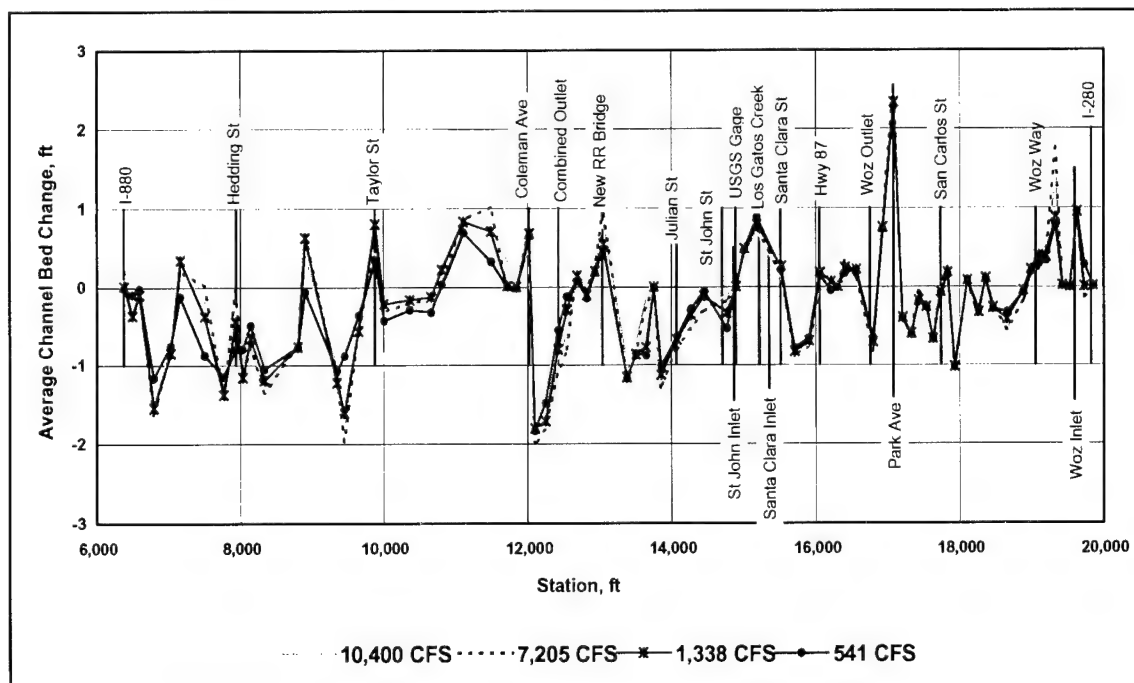Figure 27. Guadalupe River below I-280, 1995 flood, rising limb

Figure 28. Guadalupe River below I-280, 1995 flood, falling limb

Conclusions of Adjustment Study

The adjustment study results show a bed response consistent with field observations. Thus, although it is not feasible to produce a calibrated numerical model with available data, the numerical model can be used to compare generalized bed response for existing conditions to generalized bed response with project conditions. The purpose of the model study was to evaluate the effect of project features on aggradation and degradation in the Guadalupe River. This can be satisfactorily accomplished using the uncalibrated model. The model should not be used to make quantitative predictions about future degradation or aggradation.

Numerical Model Sensitivity

Numerical model results are subject to the boundary conditions specified. These boundary conditions include the sediment inflow and the depth of the bed sediment reservoir where sediment is available for entrainment. As discussed in Chapter 2, there are uncertainties associated with the boundary conditions, due to both the lack of available field measurements and the natural variability associated with these parameters. To provide confidence in interpreting model results, sensitivity studies were conducted to determine the significance of assigned boundary conditions where uncertainty was highest. Sensitivity of model predictions to sediment inflow assignments and the depth of the bed sediment reservoir were evaluated. The 7-year hydrograph simulating the period October 1992 – September 1999 was used in the sensitivity evaluations. This hydrograph includes both flood events and low flows and is considered appropriate for the sensitivity evaluation.

Total sediment inflow

There is considerable uncertainty associated with the sediment inflow to both the Guadalupe River and Los Gatos Creek. The Guadalupe River is an underfit stream where incising has been checked in many locations by natural and/or constructed grade control structures. Measurements of the bed-material load were not available and it was difficult to find a fully-alluvial reach where sediment transport theory could be applied. Adequate survey data for model calibration were not available. Los Gatos Creek has several fully-alluvial reaches where sediment transport theory could be applied, but channel survey data were not available to determine hydraulic parameters. The sensitivity of numerical model predictions to the specified sediment inflow was evaluated by doubling and halving the sediment inflow for all size classes at all discharges. Results are shown in Figure 29.
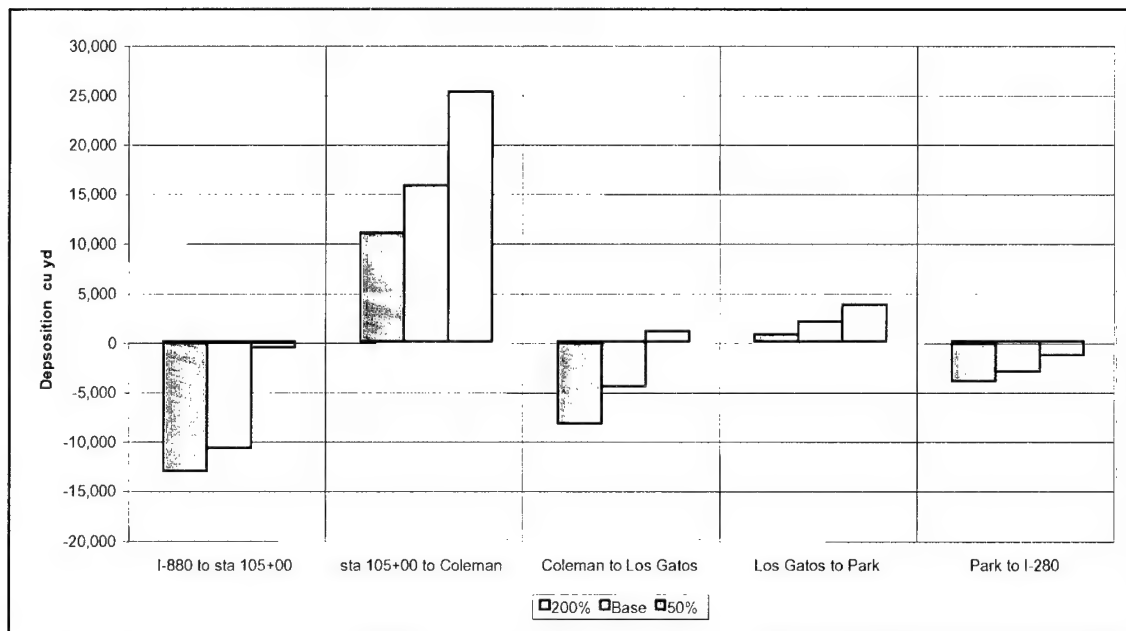
Figure 29. Sensitivity of numerical model results to total sediment inflow at upstream boundaries on both Los Gatos Creek and Guadalupe River during 7-year hydrograph. Sediment inflows 200 percent and 50 percent of base sediment inflow were evaluated

The numerical model predicts more degradation and less aggradation with less sediment inflow. With the base sediment inflow specification, the net calculated degradation in the study reach between I-880 and I-280 is 500 yd^3. When sediment inflow is reduced by 50 percent, net degradation is 13, 700 yd^3. When sediment inflow is increased by 100 percent, net aggradation of 28,100 yd^3 is calculated.

Very-fine to medium sand inflow

Model sensitivity to very-fine to medium sand inflow was evaluated. These sands between 0.062 mm and 0.50 mm were not found in significant (greater than 10 percent) quantities in the streambed and were therefore considered to be components of the wash load. However, these size classes are expected to deposit on the floodplain downstream from Coleman Avenue when overbank flow occurs during high flows and therefore should be included in the numerical model. In addition, even though not present in significant quantities in the streambed, these finer sands are still present and are subject to removal by hydraulic sorting. The very-fine to medium sand inflow to the model was reduced by 50 percent and removed completely in the sensitivity evaluations. Results are shown in Figure 30.
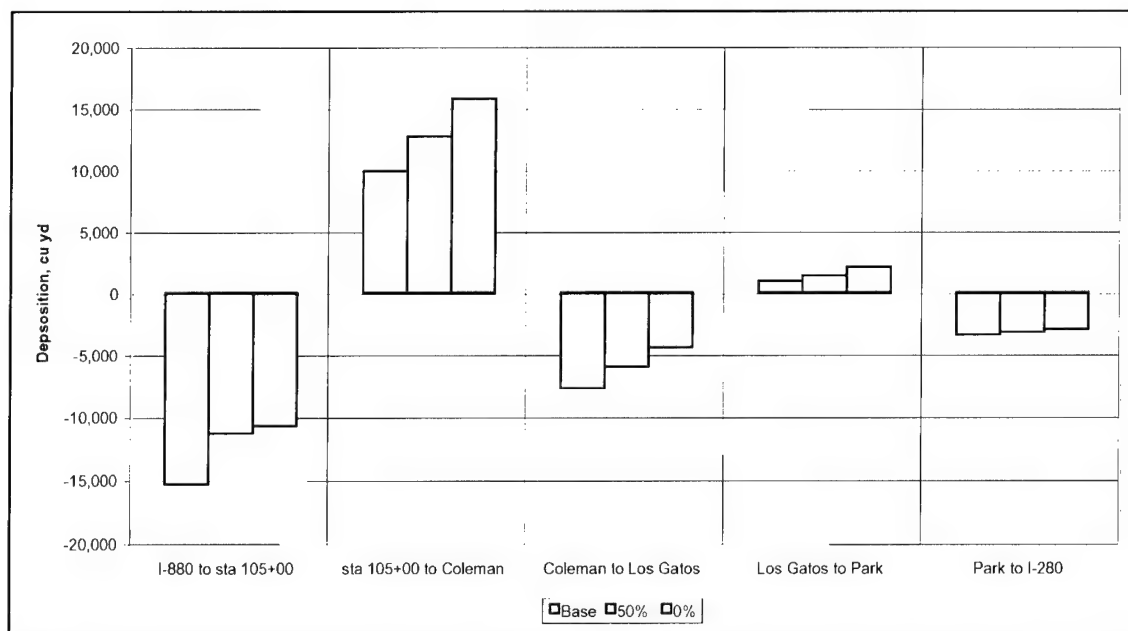
Figure 30.   Sensitivity to very-fine to medium sand inflow during the 7-year hydrograph.
Fifty percent and 0 percent of the very-fine to medium sand base inflow were evaluated

The sensitivity evaluation indicated that reducing the very-fine to medium sand inflow increases degradation during the 7-year hydrograph. This is a consequence of removal of these size classes from the model's bed-sediment reservoir during the numerical simulation. Net degradation in the study reach increased from 500 yd^3 for the base condition to 6,100 yd^3 when the finer sand inflow was reduced by 50 percent, and to 15, 400 yd^3 when the finer sand inflow was eliminated. Deposition downstream from Coleman Avenue to sta 105+00 still occurs when the very-fine to medium sand classes are removed from the sediment inflow.

Bed-material load inflow

The bed-material load is the primary component of the sediment load that influences channel behavior. Bed-material load in this study includes sediment size classes between 0.50 and 32.0 mm. The sensitivity of numerical model predictions to the specified bed-material inflow at the upstream model boundaries was evaluated by reducing the bed-material sediment inflow on both the Guadalupe River and Los Gatos Creek by 50 percent of the base, by increasing bed-material sediment inflow on both the Guadalupe River and Los Gatos Creek to 200 percent of the base, and by increasing bed-material sediment inflow on just Los Gatos Creek to 200 percent of the base. Calculated results are shown in Figure 31.
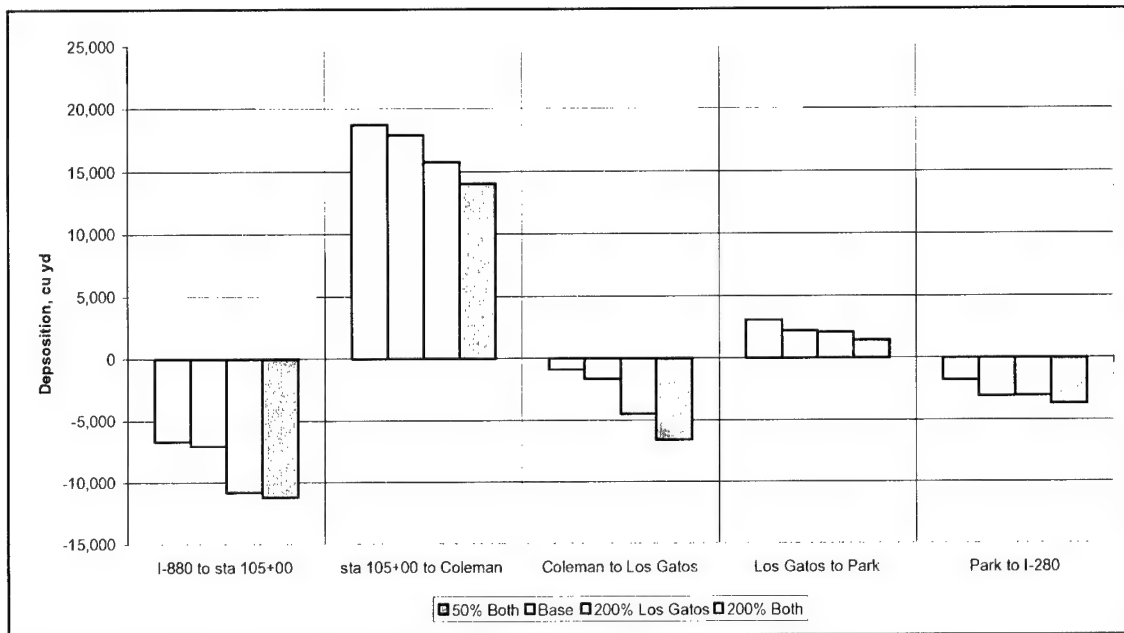
Figure 31. Sensitivity to bed-material sediment inflow during the 7-year hydrograph. Fifty percent and 200 percent of the base bed-material sediment inflow on both the Guadalupe River and Los Gatos Creek and 200 percent of the base bed-material sediment inflow on just Los Gatos Creek were evalutated

Figure 31 shows that general aggradation and degradation trends were not affected by the range of conditions in the sensitivity evaluation. Net degradation in the study reach increased from 500 yd^3 for the base condition to 5,600 yd^3 when the bed-material sediment inflow was reduced by 50 percent. Net aggradation was calculated in the study reach when the bed-material sediment inflow was increased to 200 percent of the base condition. When bed-material sediment inflow was increased on just Los Gatos Creek, 8,700 yd^3 more deposition occurred than with the base condition. When bed-material sediment inflow was increased to 200 percent of the base condition on both the Guadalupe River and Los Gatos Creek, 12,900 yd^3 more deposition occurred than with the base condition.

Bed-sediment reservoir

The bed-sediment reservoir depth was specified at 5 ft in reaches of the Guadalupe River that appeared to be alluvial. The bed-sediment reservoir depth was specified to be zero where natural or constructed grade control structures were observed. The bed serves as a source of sediment for the river system, and sediment scoured in the upper reaches of the river may deposit or retard degradation in the lower reaches. The specified bed-sediment reservoir depth at a cross section also affects the ultimate depth of scour that can occur at that location. The bed-sediment reservoir depth was increased from 5 ft to 10 ft and reduced to 1 ft for the sensitivity evaluation. Hard points remained in place. Calculated differences in average bed change are shown in Figure 32. Calculated differences in net deposition volumes are shown in Figure 33.
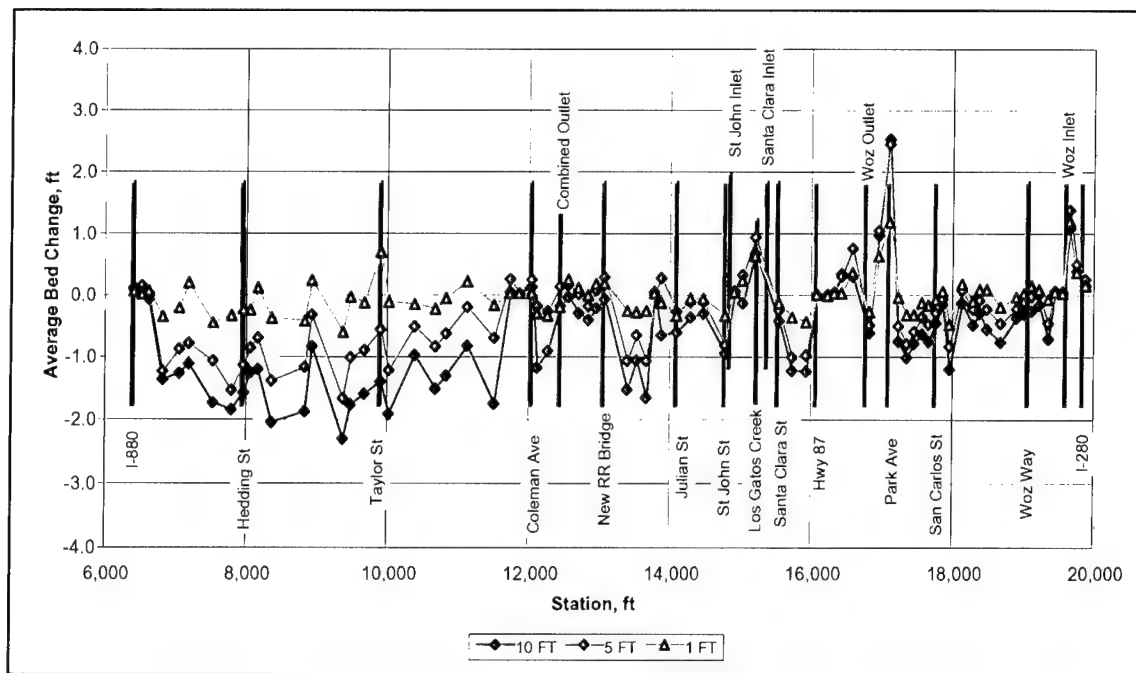
Figure 32. Sensitivity of average bed change to bed-sediment reservoir depth during 7-year hydrograph. Bed-sediment reservoir depths of 10, 5, and 1 ft were evaluated
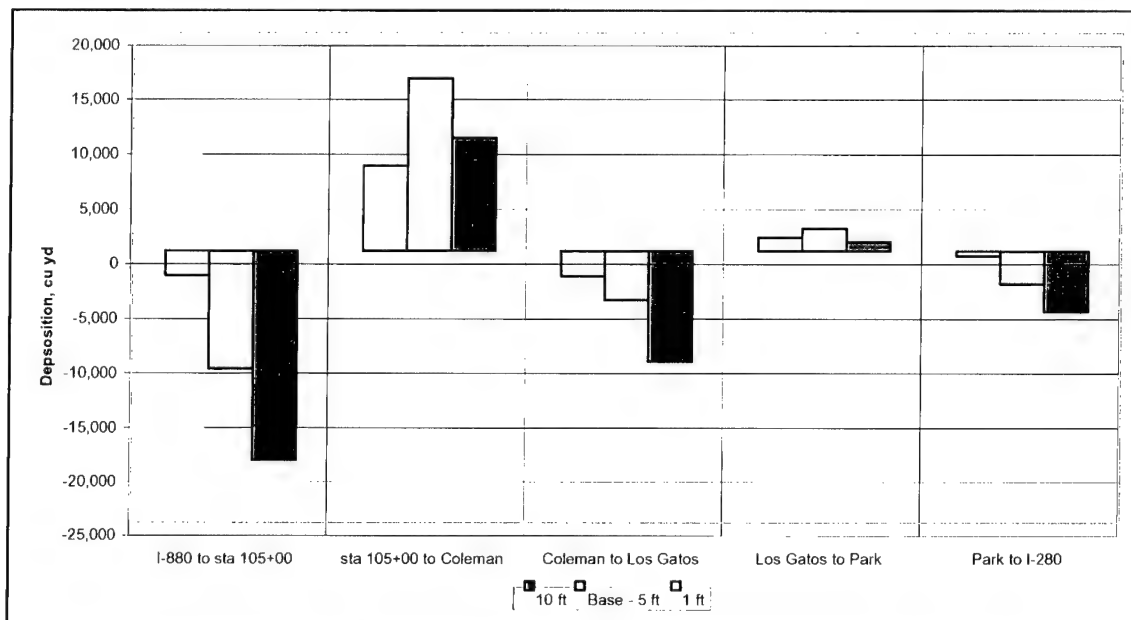

Figure 33. Sensitivity of reach deposition to bed-sediment reservoir depth during 7-year hydrograph. Bed-sediment reservoir depths of 10, 5, and 1 ft were evaluated

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Figure 32 shows that increasing the bed-sediment reservoir depth from 5 ft to 10 ft resulted in a maximum increase in degradation of less than 1 ft. Net aggradation of 4,000 yd^3 was calculated in the study reach when the bed-sediment reservoir was specified at 1 ft deep. Net degradation of 23,700 yd^3 was calculated when the bed-sediment reservoir was specified at 10 ft deep.

Conclusions of Sensitivity Study

Numerical model results were found to be sensitive to both the specified sediment inflow and the specified bed-sediment reservoir depth. Considerable uncertainty is associated with assignment of these boundary conditions. Using the adjusted numerical model boundary conditions, the net calculated degradation in the study reach between I-880 and I-280 was 500 yd^3 at the end of the 7-year simulation. When total sediment inflow was reduced by 50 percent, net degradation was 13,700 yd^3. When total sediment inflow was increased by 100 percent, net aggradation of 28,100 yd^3 was calculated. Calculated results were found to be sensitive to both the wash load and the bed-material load. The thickness of the bed sediment reservoir was also found to influence results. Increasing the bed sediment reservoir thickness in alluvial reaches from 5 ft to 10 ft resulted in a calculated net degradation of 23,700 yd^3 but a maximum increase in thalweg degradation of less than 1 ft during the 7-yr hydrograph. Reducing the bed sediment reservoir thickness to 1 ft resulted in net aggradation of 4,000 yd^3. These uncertainties must be considered when interpreting numerical model results. Quantitative predictions from the numerical model are somewhat unreliable. The sensitivity study provides an indication of input uncertainties on study results. Although the magnitudes of the study results are affected by these boundary condition uncertainties, calculated trends in specific reaches do not seem to be significantly affected, so that comparisons between existing and alternative project conditions are deemed reliable.

4 Project Evaluation

Effect of Project Features

The numerical model was used to evaluate three project design features: channel widening and hydraulic roughness reduction, high-flow bypassing, and sediment bypassing. The numerical model provides a useful way to determine the relative importance of each of these features in terms of how long-term sedimentation processes and geomorphology are affected by their inclusion in the project design. Using the existing channel geometry and a 7-year hydrograph (1992-1999) aggradation and degradation were calculated. This was the base condition to which calculations with the three design features were compared.

First, the effects of channel conveyance improvements were determined by changing the model geometry in the numerical model to design conditions. The project design included channel widening and hydraulic roughness reduction upstream from Coleman Avenue. A constant design Manning's roughness coefficient of 0.040 was assigned to the reach between sta 120+93 and 124+25. Between Santa Clara Street and Park Avenue, the project design included channel widening, bed armoring and hydraulic roughness reduction. A constant design Manning's roughness coefficient of 0.025 was assigned to the reach between sta 157+50 and 170+79. Upstream from Woz Way and through I-280 the design included channel widening and hydraulic roughness reduction. A constant design roughness coefficient of 0.043 was used in the reach between sta 189+85 and 199+05. Next, the effect of high-flow bypassing was evaluated by adding the flow diversions at the Woz Way, St. John and Santa Clara bypasses to the new geometry in the numerical model. Finally, sediment diversions through the bypasses were added to the numerical model. Calculated net aggradation and degradation for five reaches of the Guadalupe River for the three cases are compared to existing conditions in Figure 34 and Table 4. The effect of channel widening and hydraulic roughness reduction is labeled DES1; the effect of the reducing flood flows in the channel by diverting flow through the bypasses is labeled DES2; and the effect of including sediment in the bypassed flow is labeled DES3. DES3 includes all the project features and represents the actual project design condition. From Table 4 it can be determined that the calculated cumulative net effect for the 7-year hydrograph was 3,420 yd^3 (490 yd^3/year) more degradation with project conditions (DES3) than for existing conditions.
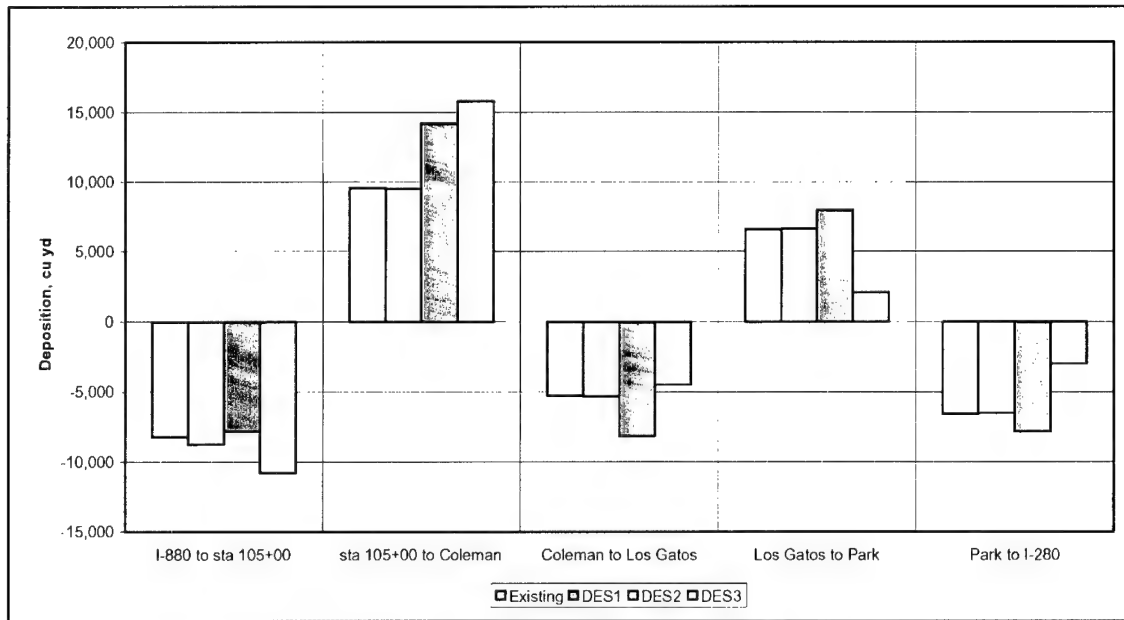
Figure 34. Calculated deposition in five reaches from 7-year hydrograph (1992-1999)

Table 4
Calculated Deposition in Five Reaches 1992-1999 Hydrograph, cu yd

	Existing Conditions	Channel Widening DES1	Channel Widening and Bypass Flows DES2	Channel Widening, Bypass Flows and Sediment Bypassing DES3
I-280 to Park Avenue	-3,000	-7,810	-6,520	-6,550
Park Avenue to Los Gatos Creek	2,060	8,000	6,620	6,570
Los Gatos Creek to Coleman Avenue	-4,500	-8130	-5,290	-5,280
Coleman Ave to Sta 105+00	15,760	14,220	9520	9,590
Sta 105+00 to I-880	-10,780	-7,780	-8,710	-8,210
Cumulative for Study Reach	-460	-1500	-4380	-3880

Calculated cumulative sediment transport during the 7-year hydrograph in the Guadalupe River and through the bypasses is shown in Table 5.

Table 5
Calculated Cumulative Sediment Transport with Project Design (DES3) 1992-1999 Hydrograph, cu yd

Location	
Guadalupe River at I-280	56,410
Woz Way Bypass	390
Guadalupe River at Santa Clara Street	56,990
Santa Clara Bypass	480
Los Gatos Creek	49,420
St John Bypass	1,290
Guadalupe River at Coleman Avenue	111,080
Guadalupe River at I-880	109,700

Channel widening and reducing hydraulic roughness through the I-280 bridges, between Santa Clara Street and Park Avenue, and upstream from Coleman Avenue result in lower water-surface elevations. These project features cause channel velocities to be higher for a given discharge, especially during flood flows when channel capacity is significantly increased. Figure 35 shows a backwater profile calculation for a condition without bypass flow where the discharge downstream from the Los Gatos confluence is 2,500 cfs and the discharge upstream from the confluence is 1,400 cfs. The figure shows a slight decrease in water-surface elevation upstream from Coleman Avenue due to channel widening. Upstream from Santa Clara Street the channel widening and hydraulic roughness reduction has a much more significant effect on water-surface elevations. Figure 35 also shows a decrease in water-surface elevation due to channel widening at the I-280 bridges. The same trend is shown in Figure 36 with higher discharges. In this case the backwater profile was calculated for a combined discharge from Los Gatos Creek and the Guadalupe River of 12,000 cfs, with 6,700 cfs coming from the Guadalupe River. In Figure 36 the existing condition water-surface profile and the DES1 water-surface profile show the effects of channel widening and hydraulic roughness reduction. With the higher discharge the effect of widening upstream from Coleman Avenue is more significant than at lower discharges. In the same figure, the DES3 profile shows the additional reduction in water surface caused by reduction in channel discharge due to bypassing some of the flow.

The effect of decreasing the downstream water-surface elevation is higher velocities and more degradation in the Park Avenue to I-280 reach for discharges below 1,500 cfs. This is the Guadalupe River discharge at which flow begins to be diverted into the Woz Way bypass. Above 1,500 cfs the effect of lower downstream water-surface elevations on channel velocity and degradation is countered to some extent by the reduction in channel discharge due to bypassed flow. The cumulative net effect for the 7-year hydrograph is more degradation with project conditions than for existing conditions. Figure 34 shows that the project feature most responsible for this increase in degradation is channel
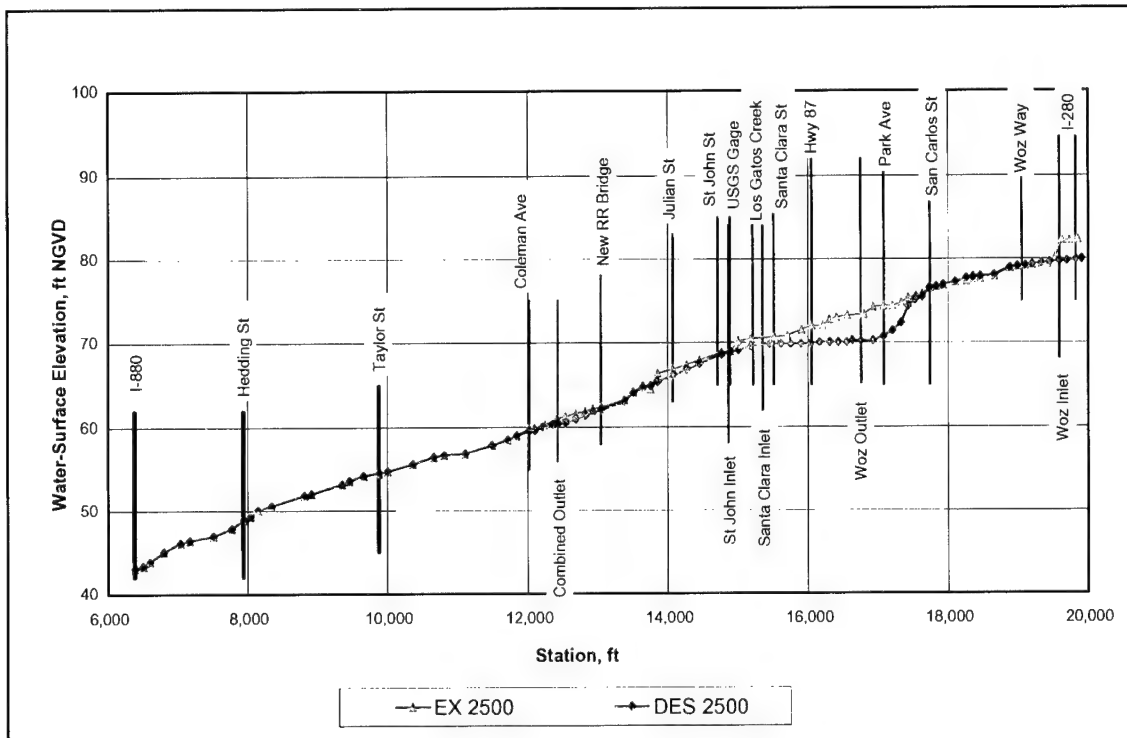
Figure 35. Calculated water-surface elevations for a discharge of 2,500 cfs downstream from Los Gatos Creek and 1,400 cfs upstream
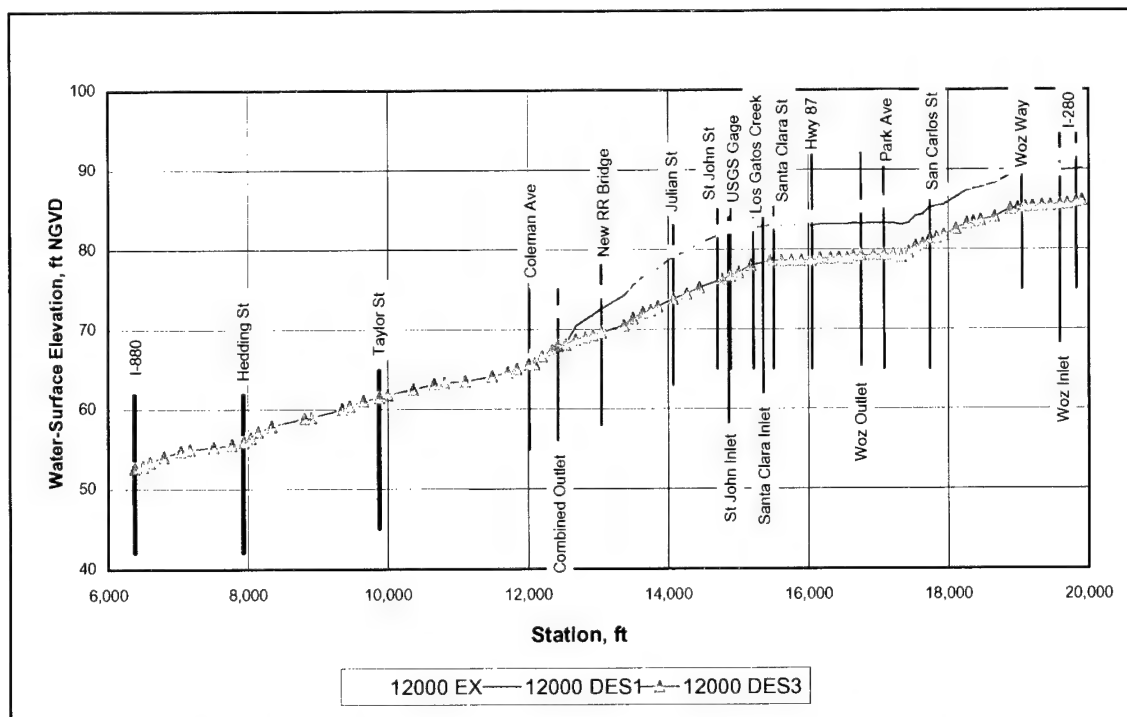

Figure 36. Calculated water-surface profiles for combined Los Gatos Creek and Guadalupe River discharge of 12,000 cfs and 6,700 cfs on Guadalupe River

widening and hydraulic roughness reduction (DES1). When the effects of flow diversion through the Woz Way bypass are included in the simulation (DES2), calculated degradation is reduced. Allowing sediment from the main channel to be diverted into the Woz Way bypass (DES3) results in a negligible change in the reach degradation. For the 7-year simulation, the quantity of sediment diverted is very small compared to the total sediment transported through the reach as shown in Table 5. The most significant feature in this reach in terms of geomorphic effects on the channel is channel widening; the effect of diverting flow and sediment is minor.

Downstream from Park Avenue to Los Gatos Creek the prevailing geo-morphic trend with the 7-year hydrograph is aggradation for both existing and project conditions. Long-term aggradation is greater with project conditions. The most significant project feature responsible for this increase in deposition is channel widening (DES1). The reduction in hydraulic roughness tends to increase velocity and reduce deposition in this reach, but its effect is apparently over-shadowed by the effect of channel widening. Channel widening in this reach not only induces deposition in this reach, but also reduces water-surface elevations in the upstream reach, which in turn induces upstream degradation, increasing sedi-ment inflow to this reach. Deposition is slightly less when the Woz Way bypass is included in the simulation because scour potential in the upstream reach is reduced (DES2). Including sediment in the bypassed flow (DES3) has a negligi-ble effect on the 7-year channel morphology. As in the reach upstream, channel widening in this reach is the most significant project feature in terms of geomorphic effects on the channel.

The one-dimensional numerical model results in the reach between Los Gatos Creek and Park Avenue were somewhat different than physical model results (Rahmeyer 2001). Although both models predicted deposition in this reach, the physical model indicated that deposition would occur on the right side of the channel, effectively narrowing the channel and producing higher velocities on the left side of the main channel. This result demonstrates a limitation of the one-dimension model, which is based on average hydraulic parameters.

In the reach between Los Gatos Creek and Coleman Avenue, degradation is the dominant long-term process for both existing and project conditions. Project conditions slightly increased the degradation trend. This increase can be attri-buted to channel widening upstream from Coleman Avenue, removal of the encased pipeline under Old Julian Street, and lowering of the USGS weir. Project features that alter the channel geometry are responsible for inducing this long-term degradation trend (DES1). The bypasses tend to reduce the degradation trend (DES2). This is attributed to the reduction in scour associated with flood flows when the bypasses are included in the simulation. Including sediment in the bypassed flow (DES3) has a very small effect on the 7-year channel morphology.

The reach immediately downstream from Coleman Avenue to sta 105+00 reacts differently depending on flow magnitude. During floods, when floodplain flow occurs, deposition is the dominant process. However, when the flow is con-tained within the channel, degradation is the dominant process. This is shown in

Figure 37, where calculated average bed change in the channel is shown, and Figure 38, where calculated change in thalweg is shown. With the 1992-99 hydrograph, which includes both discharges contained in the channel and discharges with overbank flow, net degradation is calculated in the channel. However, during the 1-percent chance exceedance hydrograph, where floodplain flow occurs most of the time, aggradation is calculated in both the channel and overbank. Calculations indicate that the net trend in this reach is aggradation for both the 7-year hydrograph and the 1-percent chance exceedance hydrograph. Project features tend to reduce the net aggradation in this reach. This is attributed to redistribution of sediment delivery to this reach by upstream project features. Even though more sediment is delivered with project conditions, less is delivered during floods. Upstream channel widening serves to decrease scour during floods and the bypasses further decrease channel scour during floods. Thus, the project will decrease sediment deposition on the floodplain downstream from Coleman Avenue.

The reach downstream from sta 105+00 is a degradational reach with both existing and project conditions as shown in Figure 38. Degradation is less with the project because the net sediment supplied from upstream is greater. Thus, the project will serve to reduce, but not eliminate, the long-term degradation trend in the lower reach of the Guadalupe River.

Another way of looking at calculated results is the accumulated deposition curve shown in Figure 39. This curve accumulates the calculated aggradation or degradation at each cross section starting from the downstream end of the numerical model. If aggradation is calculated at a cross section, then a positive slope is shown relative to the downstream cross section. If degradation is calculated, then a negative slope is shown relative to the downstream cross section. The upstream-most point on the curve provides the net degradation or aggradation for the entire study reach. This curve provides a more comprehensive distribution of the calculated aggradation and degradation summarized for five reaches in Figure 34 and Table 4.

This analysis shows that the most significant project feature in terms of effects on long-term channel geomorphology is change in channel geometry. High-flow bypassing tends to dampen the effects of channel geometry change. The effect of sediment diversion through the bypasses is minor. Due to the limited influence of sediment diversion on long-term aggradation and degradation trends, there is less concern related to the uncertainty associated with the assignment of sediment diversion ratios in the numerical model.

Calculated Response to Flood Hydrographs

The numerical model was used to calculate aggradation and degradation in the project reach during the passage of the 1-, 2-, 5-, and 10-percent chance exceedance floods. The flood hydrographs were determined by U.S. Army Engineer District, Sacramento (2000) and are shown in Figure 9. In the numerical model simulation, the 1993 hydrograph was used to represent antecedent flows.
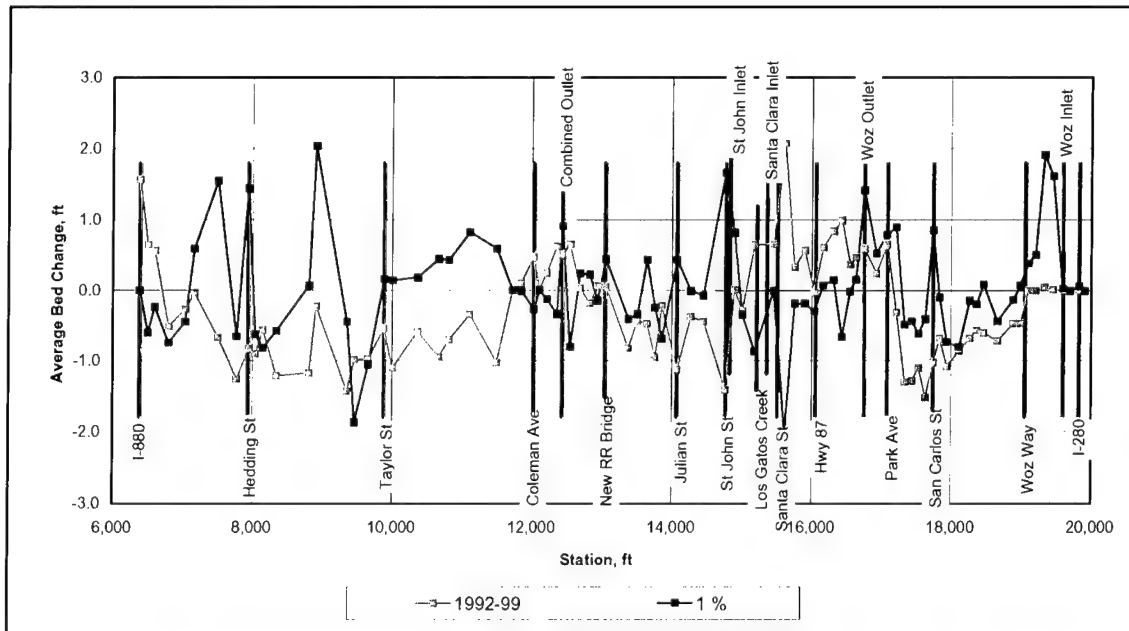
Figure 37. Calculated average bed change with project conditions for the 1992-99 hydrograph and the 1-percent chance exceedance flood hydrograph
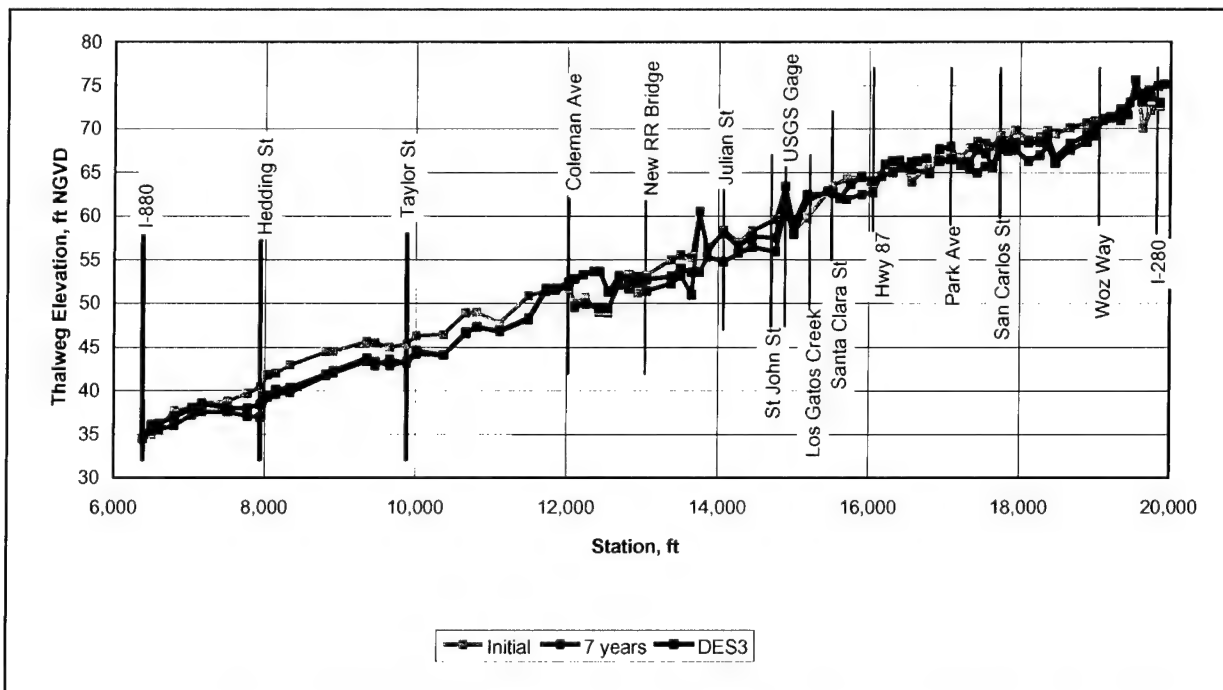

Figure 38. Calculated thalweg elevations after 7-year hydrograph (1992-1999) for existing and project (DES3) conditions
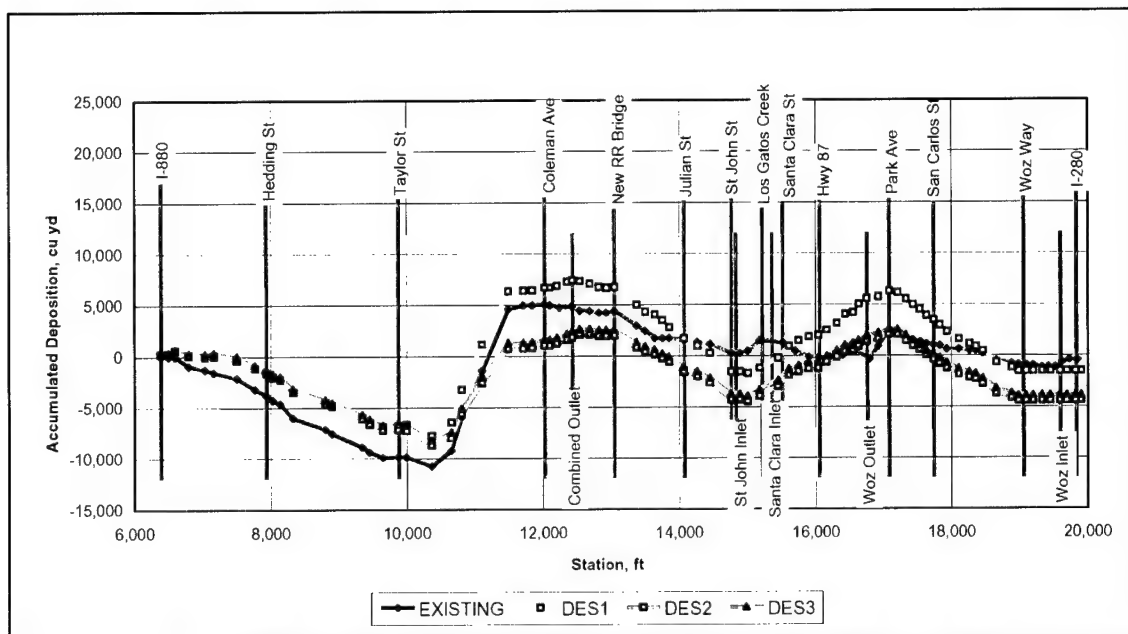
Figure 39. Calculated deposition accumulated from downstream station from 7-year hydrograph (1992-1999)

The results presented in Figure 40 and Table 6, however, reflect only the calculated changes occurring during the designated flood hydrographs.

The numerical model was also used to estimate a typical annual channel response by calculating aggradation and degradation for a 12-year hydrograph determined from the historical record and dividing the calculated total by 12. The 12-year hydrograph was obtained by removing the 1995 hydrograph from the 1992-1999 historical hydrograph and then duplicating the remaining years. The rational for removing the 1995 hydrograph was that 1995 was an exceptionally wet year. Calculated summaries of net aggradation and degradation for five reaches with project conditions are shown in Figure 40 and Table 6.

Calculations for project conditions indicate that channel response from large flood events is typically opposite the typical annual response and the long-term response. The primary cause of the difference in channel response is the increase in inflowing sediment concentration that accompanies flood flows. In the upstream reach between I-280 and Park Avenue, net degradation is calculated with an average annual flow, but net aggradation is calculated with flood flows that have exceedance frequencies of 5 percent or greater. This response is due to a combination of increased sediment inflow concentrations from upstream and deposition downstream from the Woz Way bypass inlet during floods. In the reach between Park Avenue and Los Gatos Creek, net aggradation is calculated with an average annual flow, but net degradation is calculated during floods. The channel widening in this reach results in lower velocities at low flows, but higher velocities at high flows when compared to existing conditions and conditions in the upstream reach. In the reach between Los Gatos Creek and Coleman Avenue, aggradation is calculated for the 1- and 2-percent chance exceedance floods,
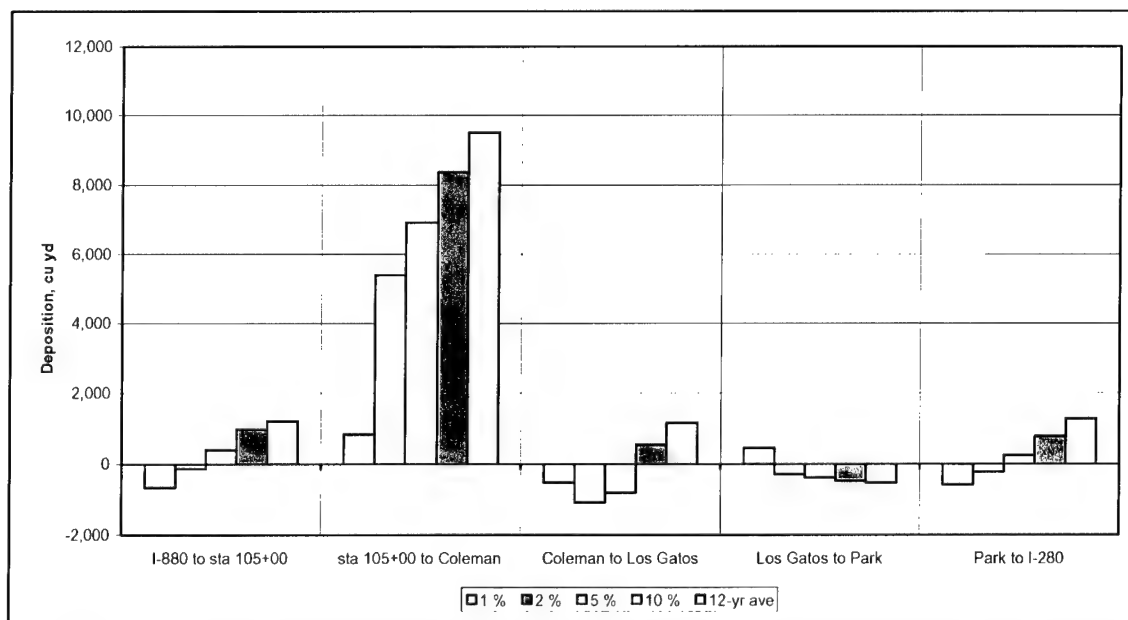
Figure 40.   Calculated deposition from flood hydrographs and 12-year average flow with project conditions

Table 6
Calculated Deposition During Flood Events with Project Conditions, cu yd

	1 Percent Chance Exceedance Flood	2 Percent Chance Exceedance Flood	5 Percent Chance Exceedance Flood	10 Percent Chance Exceedance Flood	12-Year Typical Annual Flow
I-280 to Park Avenue	1,270	780	230	-230	-590
Park Avenue to Los Gatos Creek	-520	-490	-390	-300	440
Los Gatos Creek to Coleman Avenue	1,150	540	-800	-1,090	-520
Coleman Avenue to sta 105+00	9,520	8,380	6,920	5,400	830
sta 105+00 to I-880	1,200	970	380	-130	-670
Cumulative for Study Reach	12,620	10,180	6,340	3,650	-510

while degradation is calculated for the 5- and 10-percent exceedance floods and the average annual flow. The most significant difference is in the reach downstream from Coleman Avenue to sta 105+00. During floods, significant deposition occurs on the floodplain, while with average annual flows there is considerably less overbank flow and floodplain deposition. In the most downstream reach, between sta 105+00 and I-880, flood hydrographs with exceedance frequencies of 5 percent and greater continue to produce aggradation, while the average annual flows produce degradation.

The numerical model was used to compare existing channel response during flood hydrographs to channel response with the project. Calculated summaries of net aggradation and degradation for five reaches with existing conditions are shown in Table 7. Figure 41 shows channel response in five summary reaches for the 1-percent chance exceedance flood and from the typical annual hydrograph. Figures 42 through 45 compare accumulated deposition from the downstream end of the numerical model for existing and project conditions for the 1-, 2-, 5-, and 10-percent chance exceedance floods, respectively. Figure 46 compares accumulated deposition from the downstream end of the numerical model from existing and project conditions for the 12-year hydrograph. Recall that if aggradation is calculated at a cross section, then a positive slope relative to the downstream cross section is shown on the accumulated deposition figure. If degradation is calculated, then a negative slope is shown relative to the

Table 7
Calculated Deposition During Flood Events with Existing Conditions, cu yd

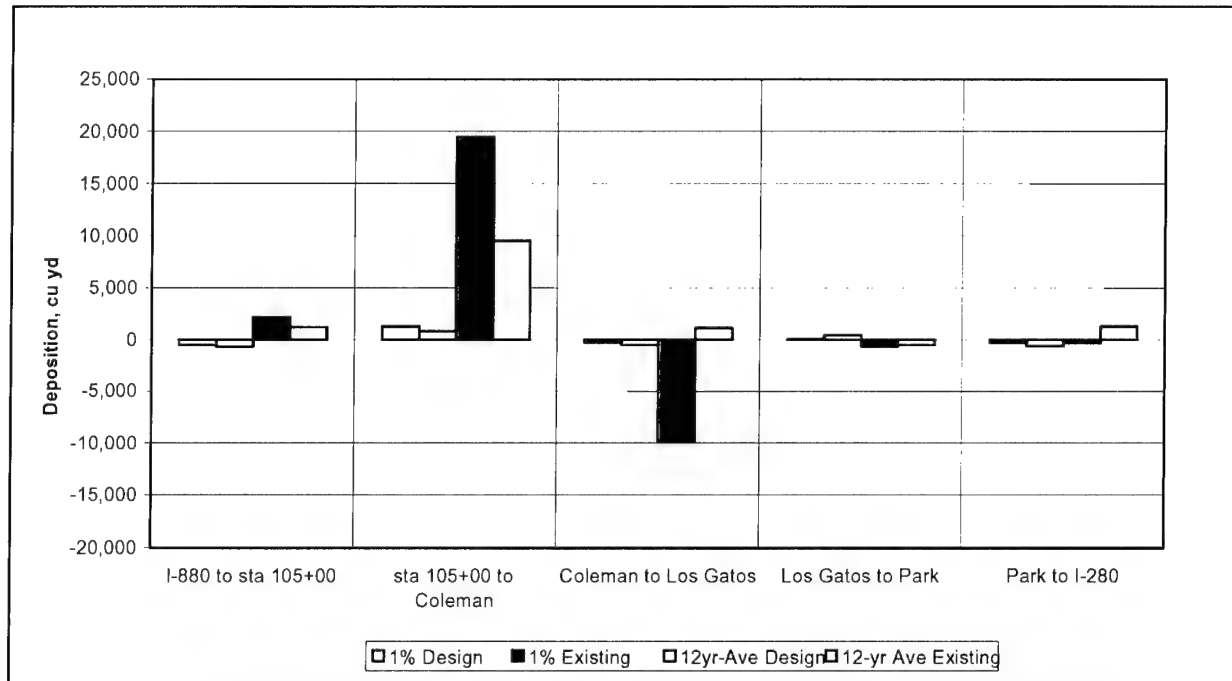|	1 Percent Chance Exceedance Flood	2 Percent Chance Exceedance Flood	5 Percent Chance Exceedance Flood	10 Percent Chance Exceedance Flood	12-Year Typical Annual Flow
I-280 to Park Avenue	-360	-300	-220	-610	-320
Park Avenue to Los Gatos Creek	-630	-880	-1,110	-1,180	90
Los Gatos Creek to Coleman Avenue	-9,930	-8,150	-4,990	-2,780	-270
Coleman Avenue to sta 105+00	19,500	16,810	11,430	7,840	1,270
sta 105+00 to I-880	2,180	1,060	460	-100	-520
Cumulative for Study Reach	10,760	8,540	5,570	3,170	250

Figure 41. Calculated deposition for existing and project conditions with the 1-percent chance exceedance flood and the 12-year typical flow
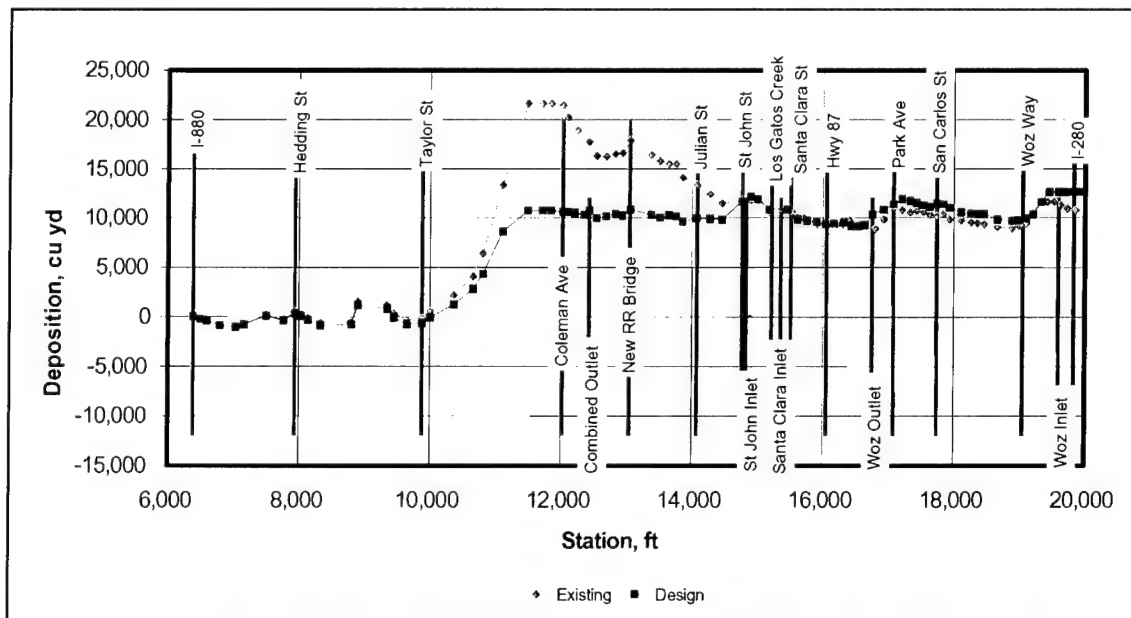

Figure 42. Calculated deposition accumulated from the downstream cross section for the 1-percent chance exceedance flood – existing and project conditions
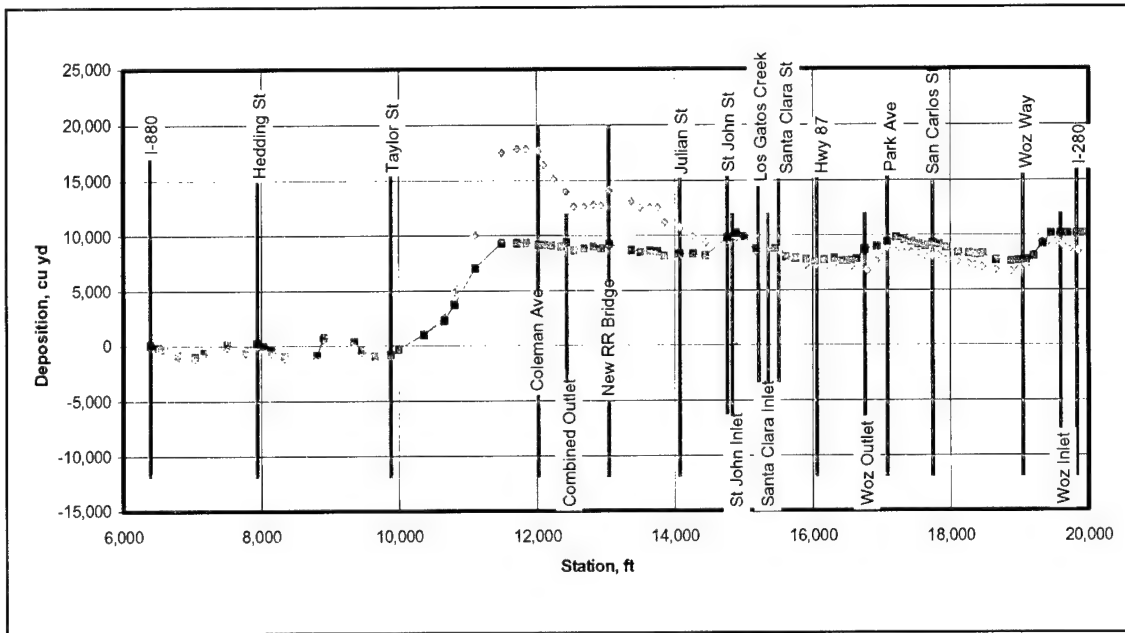
Figure 43. Calculated deposition accumulated from the downstream cross section for the 2-percent chance exceedance flood – existing and project condtions
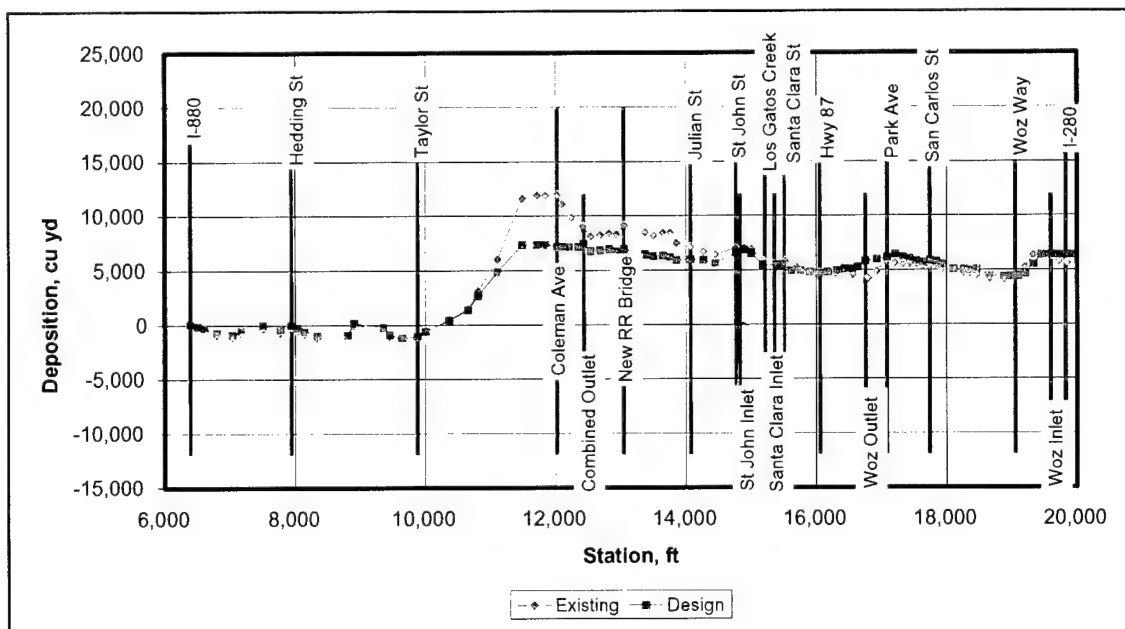

Figure 44. Calculated deposition accumulated from the downstream cross section for the 5-percent chance exceedance flood – existing and project conditions
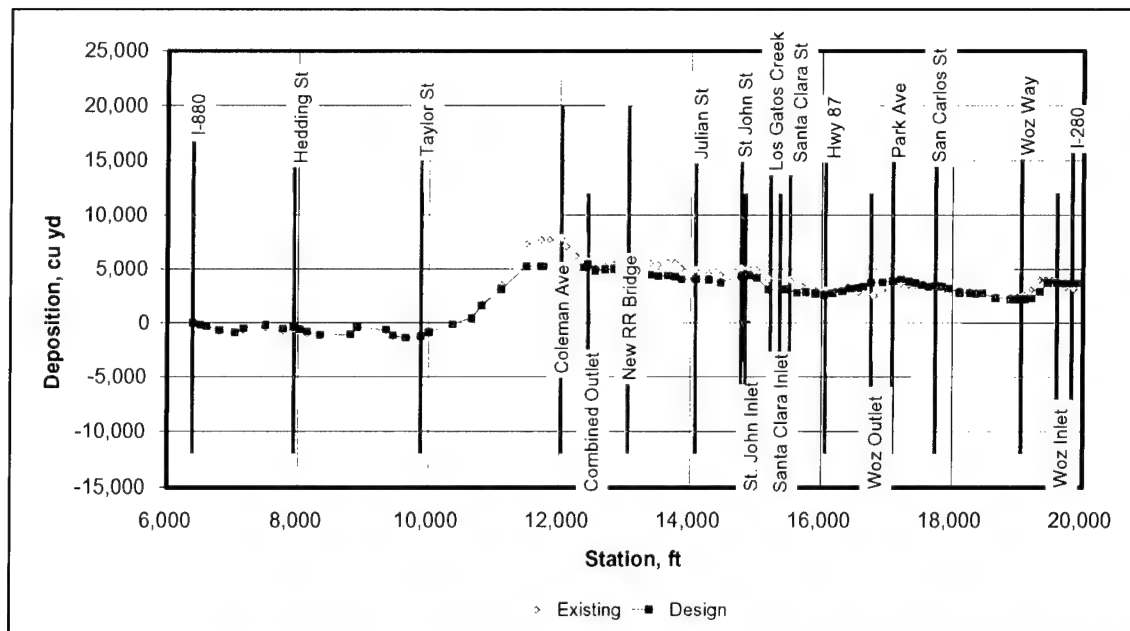
Figure 45. Calculated deposition accumulated from the downstream cross section for the 10-percent chance exceedance flood – existing and project conditions
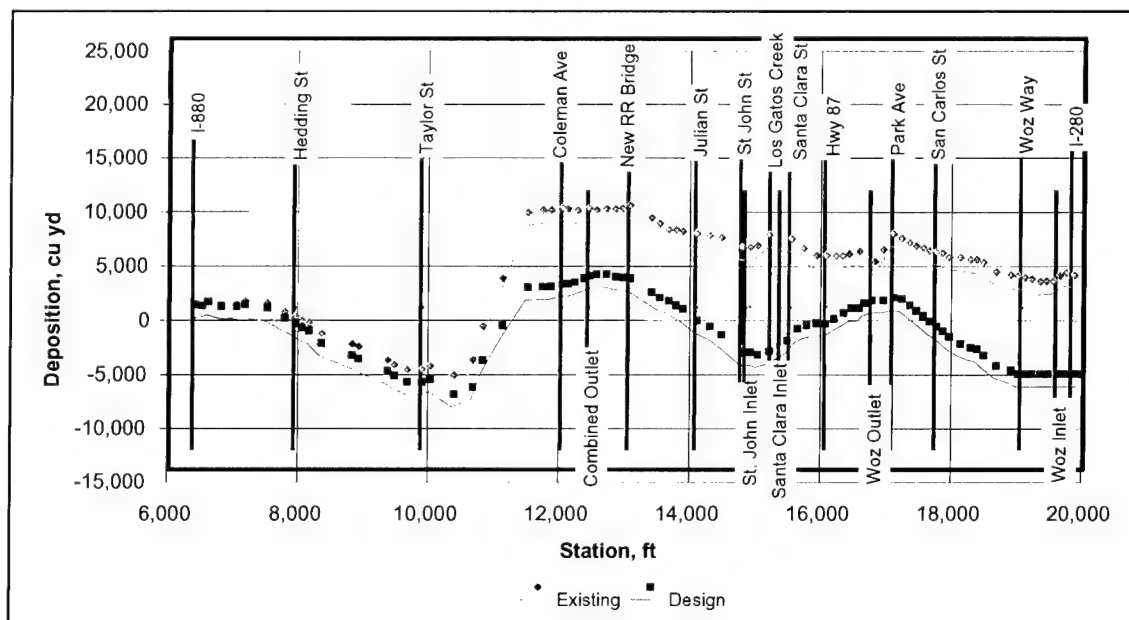

Figure 46. Calculated deposition accumulated from the downstream cross section for a 12-year hydrograph (1992-1994,1996-1999) – existing and project conditions

downstream cross section. These figures provide a comprehensive distribution of the aggradation and degradation calculated at each cross section in the numerical model. Table 7 and Figures 41 through 46 demonstrate that the most significant differences between project and existing conditions during floods are that there is less aggradation downstream from Coleman Avenue and less degradation upstream from Coleman Avenue with project conditions. This can be attributed to reduced scour potential in the natural channel reaches adjacent to the bypasses when flood discharges are being diverted. Comparing the calculated cumulative deposition for project and existing conditions in the study reach, it can be seen that calculated net aggradation was increased between 13 and 19 percent during floods with project conditions, and that calculated net degradation was increased by about 760 yd^3 during a typical year with project conditions.

Long-Term Hydrograph

The numerical model was used to evaluate channel response using a long-term hydrograph. The hydrograph selected for the simulation started with the 12-year hydrograph previously used to estimate typical annual channel response, followed by the one-percent chance exceedance flood hydrograph, followed again by the 12-year hydrograph. The 12-year hydrograph simulates the 6 years from October 1992 - September 1994 and October 1995 - September 1999. This historical period was duplicated to obtain the 12-year hydrograph. The 1995 hydrograph was excluded because that year was an exceptionally wet year. The total simulation represents a 24-year period, with a 4-day 1-percent chance exceedance flood hydrograph midway in the simulation.

Calculated aggradation and degradation in five reaches of the Guadalupe River are shown in Figure 47. Accumulated bed changes are shown in Figure 48. The long-term simulation supports previous simulations in predicting different channel responses during floods than during normal runoff events.

In the upstream reach between Park Avenue and I-280 a general degradation trend is predicted during the first 12 years. This trend is reversed during the one-percent chance exceedance flood. During the second 12 years the degradation trend continues, but at a slower rate than during the first 12 years.

Between Los Gatos Creek and Park Avenue a general aggradation trend is predicted for the two 12-year hydrographs and a general degradation trend for the 1-percent chance exceedance flood. Aggradation is less during the second 12-year hydrograph.

Between Coleman Avenue and Los Gatos Creek a general degradation trend is predicted for the first 12-year hydrograph. Aggradation is predicted for the 1-percent chance exceedance hydrograph. Degradation is predicted for the second 12-year hydrograph, but at a significantly lower rate than during the first 12 years.
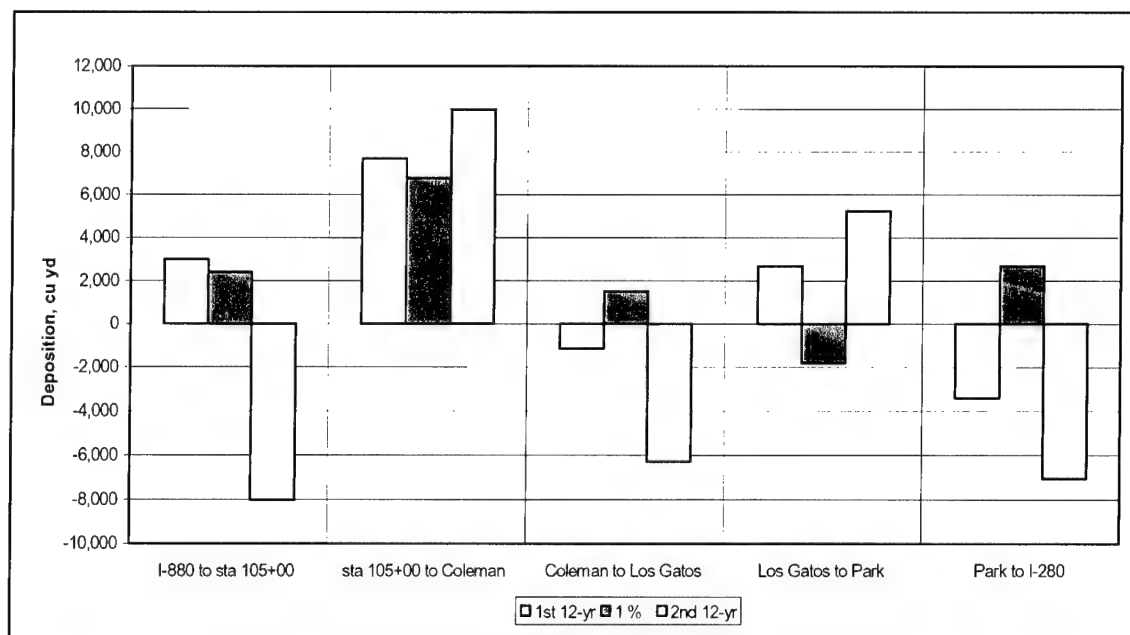
Figure 47.   Calculated deposition by reach during 24-year long-term hydrograph with project conditions
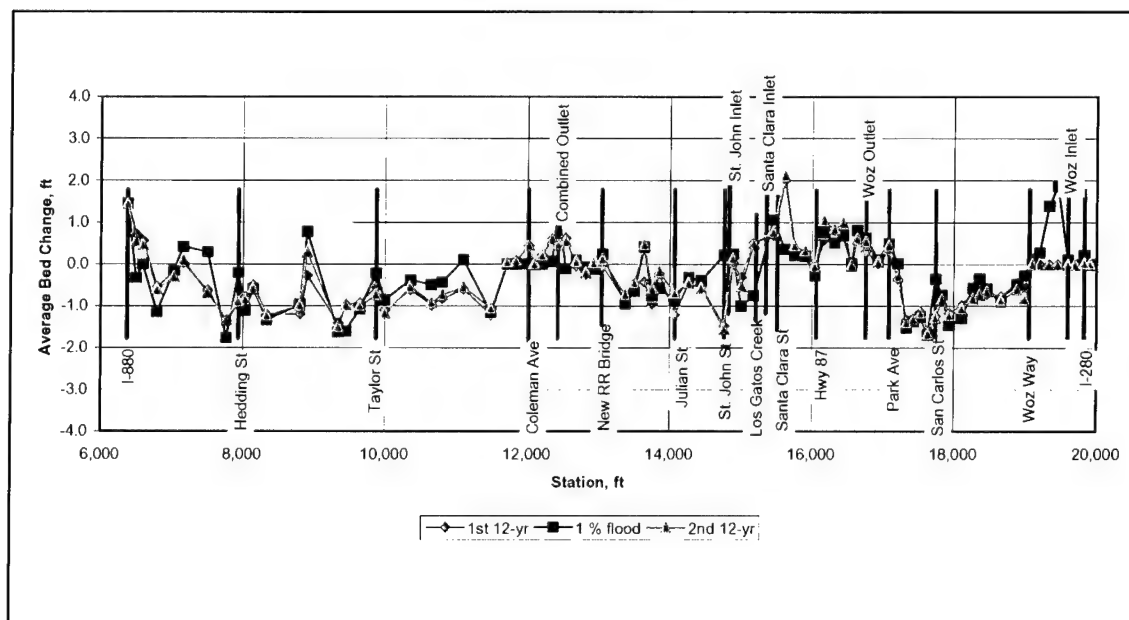

Figure 48.   Accumulated average bed change during 24-year hydrograph with project conditions

Downstream from Coleman Avenue to sta 105+00 aggradation occurs during all three periods. Most of this deposition occurs on the floodplain while the channel invert continues to degrade.

Between I-880 and sta 105+00 degradation is the dominant trend during the first 12 years, but during the 1-percent chance exceedance flood and during the subsequent 12 years the degradation trend is reversed.

Grade Control

The numerical model was used to predict channel response with the removal of the USGS weir at sta 148+87 and the addition of grade control structures to the project design. The 7-year historical hydrograph was used to evaluate the alternatives. This hydrograph includes both long-term effects and the effects of a large flood event.

Removal of the USGS weir was simulated by simply removing the weir cross section from the numerical model. The calculated deposition in five reaches of the Guadalupe River and the calculated average bed change after the 7-year hydrograph are shown in Figures 49 and 50, respectively. Results with weir removal (DES4) are compared to results with the original project design (DES3) in the figures. DES3 includes the new weir at the USGS gage. Removal of the weir results in a decrease in channel bed elevation of about 0.8 ft for about 500 ft upstream from the weir. Although not modeled, it is expected that degradation would also extend up into the Los Gatos Creek (sta 152+10) channel. The effect of removing the weir extends up to Park Avenue (sta 170+79). In the reach between Los Gatos Creek and Park Avenue, less aggradation is predicted without the weir.

Channel response to three grade control structures between Coleman Avenue (sta 120+15) and Los Gatos Creek were evaluated using the numerical model. Grade control structures were simulated at sta 133+71, Julian Street (sta (140+69) and St. John Street (sta 147+58). The new USGS weir in the original design was included in this simulation. The calculated deposition in five reaches of the Guadalupe River and the calculated average bed change after the 7-year hydrograph are shown in Figures 49 and 50, respectively. Results with grade control (DES5) are compared to results with the original project design (DES3) in the figures. DES3 includes the new weir at the USGS gage. The grade control structures reduce scour in the Coleman Avenue to Los Gatos Creek reach, but induce some additional degradation downstream from Coleman Avenue.
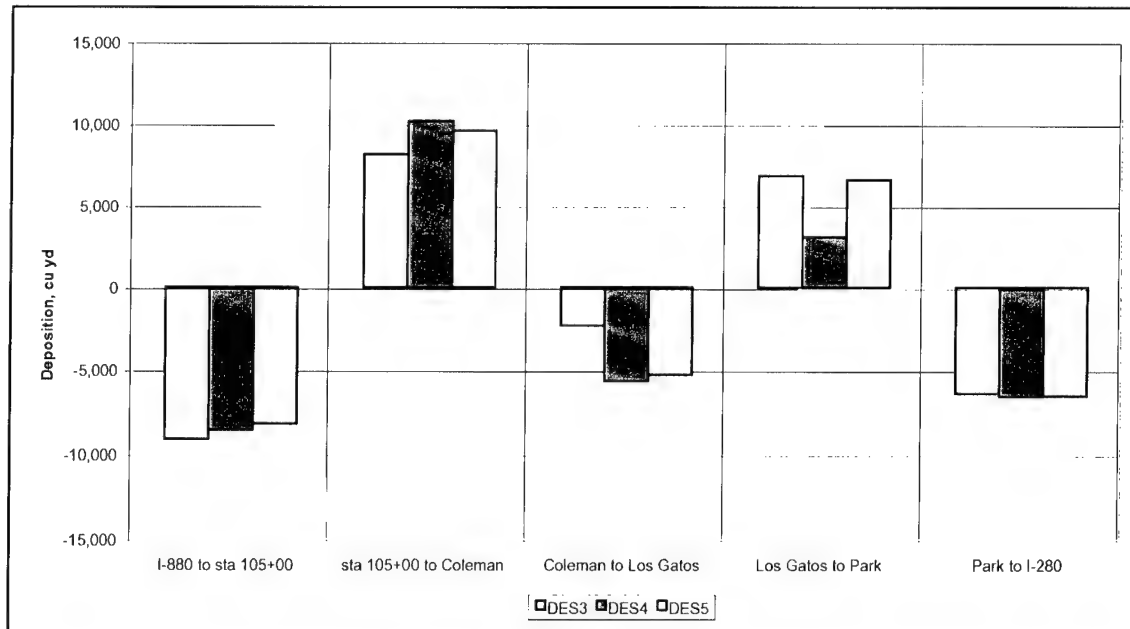
Figure 49. Calculated deposition in five reaches during 7-year hydrograph (1992-99) with grade control alternatives. DES3 is project conditions without grade control but includes the new weir at USGS gage. DES4 is USGS gage weir completely removed. DES5 is grade control at sta 133+71, Julian Street and St. John Street and a new weir at USGS gage
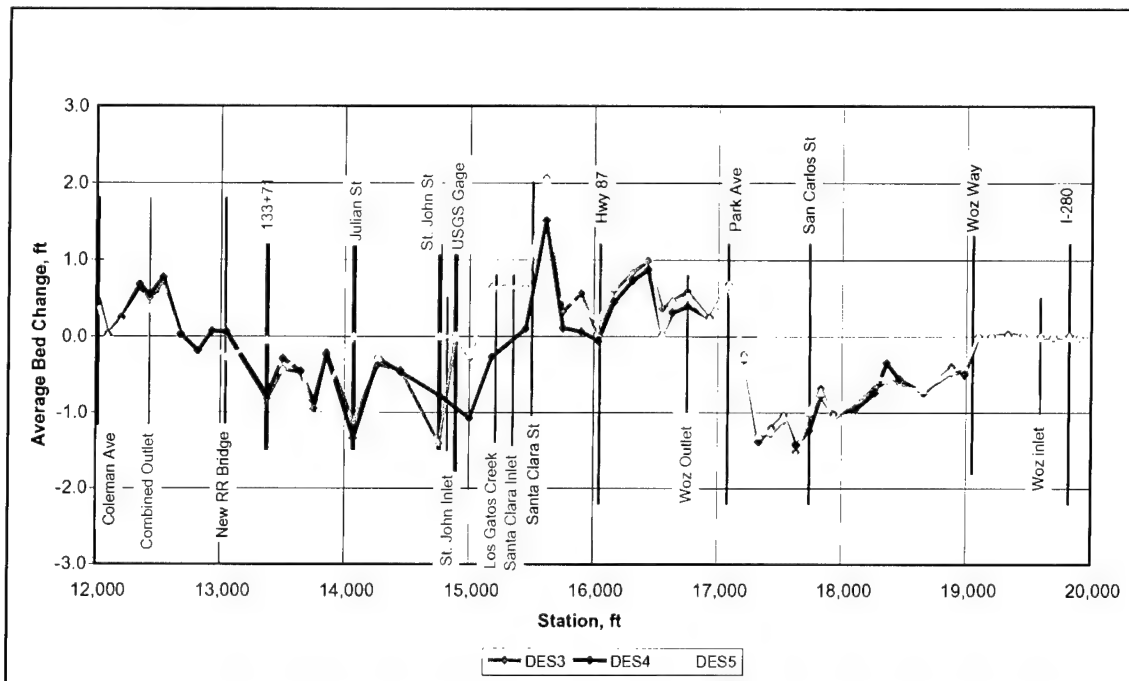

Figure 50. Calculated average bed change during 7-year hydrograph (1992-99) with grade control alternatives. DES3 is project conditions without grade control but includes the new weir at USGS gage. DES4 is USGS gage weir completely removed. DES5 is grade control at sta 133+71, Julian Street and St. John Street, and a new weir at USGS gage

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5   Conclusions and Recommendations

Conclusions

A numerical sedimentation study of 3 miles of the Guadalupe River through San Jose, CA, was conducted to evaluate the potential impact of a proposed flood-control project on channel stability in terms of channel aggradation and degradation. Both long-term channel response and response during flood events were evaluated. Due to the lack of available data for model calibration, study conclusions were based on comparisons of channel response with existing channel conditions to channel response with the project conditions.

The bed-material load in the Guadalupe River is unknown. There are no known measurements of the sediment size fractions found in significant quantities in the channel bed deposits. There are no extensive fully-alluvial reaches where sediment transport can be calculated with a high degree of confidence. Of all the numerical model inputs, the bed-material load has the highest degree of uncertainty. For this reason, the bed-material load was estimated using the best engineering techniques available and then was adjusted so that the numerical model would simulate reasonable responses with the existing channel geometry.

Channel bed response with existing conditions was predicted using 7 years of historical hydrologic data (October 1992-September 1999). The numerical model could not be calibrated to an actual historical response because survey data were inadequate and because channel modifications were constructed in several of the study reaches during the 7-year period. Sediment inflow to the numerical model was adjusted until reasonable channel responses during the simulation were obtained. The adjusted model predicted a stable bed in the upper reaches of the Guadalupe River upstream from Los Gatos Creek. Degradation was predicted in the reach between Coleman Avenue and Los Gatos Creek. Aggradation was predicted on the floodplain downstream from Coleman Avenue during flood events. Degradation was predicted in the channel downstream from Coleman Avenue all the way to the downstream study limit. These predictions were consistent with field observations of current geomorphic trends and with observations following the 1997 flood when deposition occurred on the newly constructed floodplain downstream from Coleman Avenue.

The 7-year simulation demonstrated that the aggradation and degradation trends in the study reach vary depending on both the magnitude of the annual runoff events and antecedent flow from previous years.

Numerical model results were found to be sensitive to both the specified sediment inflow and the specified bed-sediment reservoir depth. Considerable uncertainties are associated with these boundary conditions and must be considered when interpreting numerical model results. A sensitivity study was conducted to provide an indication of the magnitude of the uncertainty associated with the boundary conditions assigned in this study.

The numerical model was used to evaluate the three project design features: channel widening and hydraulic roughness reduction, high-flow bypassing, and sediment bypassing. The numerical model provides a useful way to determine the relative importance of each of these features in terms of how long-term sedimentation processes and geomorphology are affected by their inclusion in the project design. The 7-year historical hydrograph was used to determine relative channel responses. Channel widening and reducing hydraulic roughness through the I-280 bridges, between Santa Clara Street and Park Avenue, and upstream from Coleman Avenue result in lower water-surface elevations and increased channel degradation upstream from Coleman Avenue to I-280. When the effects of flow diversion through the bypasses are included in the simulation, calculated degradation is less. Allowing sediment from the main channel to be diverted into the bypasses results in a negligible change in the channel response. For the 7-year simulation, the quantity of sediment diverted is very small compared to the total sediment transported through the reach. The analysis showed that the most significant project feature in terms of effects on long-term channel geomorphology is channel widening and reduction in hydraulic roughness. The second most significant feature is the high-flow bypassing, which tends to dampen the effects of channel geometry change. The effect of sediment diversion through the bypasses is minor. Due to the limited influence of sediment diversion on long-term aggradation and degradation trends, there is less concern related to the uncertainty associated with the assignment of sediment diversion ratios in the numerical model.

The numerical model was used to calculate aggradation and degradation in the project reach during the passage of the 1-, 2-, 5-, and 10-percent chance exceedance floods and a long-term hydrograph. Calculations indicate that channel response from large flood events with project conditions is typically opposite the typical annual response and the long-term response. The primary cause of the difference in channel response is attributed to the increase in inflowing sediment concentration that accompanies flood flows. The most significant difference is in the reach downstream from Coleman Avenue to sta 105+00. During floods, significant deposition occurs on the floodplain, while with typical annual flows there is considerably less overbank flow and thus much less floodplain deposition.

The numerical model was used to compare project and existing conditions during flood events. The cumulative net effect of the project was to increase aggradation in the study reach (I-280 to I-880) between 13 and 19 percent during floods. During the 1-percent-chance-exceedance flood calculated net cumulative

aggradation was increased by 1,860 yd^3. However, study results indicated that overall stability in the study reach would be improved by the project by reducing aggradation and degradation in specific reaches. The study results indicated that the project would significantly reduce degradation during floods in the reach between Los Gatos Creek and Coleman Avenue, and also significantly reduce aggradation during floods in the reach downstream from Coleman Avenue. For the 1-percent chance exceedance flood, the project reduced degradation by 11,080 yd^3 in the reach between Los Gatos Creek and Coleman Avenue and the project reduced aggradation by 9,980 yd^3 downstream from Coleman Avenue. These differences mean that overall channel stability during floods will be significantly improved by the project.

The numerical model was used to compare project and existing conditions for long-term hydrographs. Study results indicated that the long-term effect of the project would be cumulative degradation rather than aggradation. The numerical model calculated an average annual net increase in degradation of 490 yd^3 with the 7-year hydrograph (1992-1999), and an average annual net increase in degradation of 760 yd^3 with the 12-year hydrograph. This result suggests that bed stabilization measures may be appropriate in the study reach.

The numerical model was used to predict channel response with the removal of the USGS weir at sta 148+87. Using a 7-year hydrograph (1992-1999) a decrease in channel bed elevation of about 0.8 ft was calculated for about 500 ft upstream from the weir. Although not modeled, it is expected that degradation would also extend up into the Los Gatos Creek (sta 152+10) channel. The effect of removing the weir extends up to Park Avenue (sta 170+00). In the reach between Santa Clara Street and Park Avenue, less aggradation is predicted without the weir.

Channel response to three grade control structures between Coleman Avenue (sta 120+00) and Los Gatos Creek were evaluated using the numerical model and the 7-year hydrograph. Grade control structures were simulated at sta 133+71, Julian St. (sta 140+69) and St. John St. (sta 147+58). The new USGS weir in the original design was included in this simulation. The grade control structures reduce scour in the Coleman Avenue to Los Gatos Creek reach, but induce some additional degradation downstream from Coleman Avenue. Grade control will increase the long-term stability of the channel.

Recommendations

It is recommended that new surveys be conducted to provide a consistent set of channel cross sections for future studies. The survey should have at least 2-ft contour interval accuracy, and should include elevations below the waterline. A thalweg survey should be conducted to identify the depth of pools and the location of existing grade control structures. The survey should extend up Los Gatos Creek. Survey data on Los Gatos Creek would provide more reliability to sediment inflow estimates and to channel capacity during floods.

Uncertainties related to sediment transport of both wash load and bed-material load can be reduced by starting a sediment measurement program on both the Guadalupe River and Los Gatos Creek. The suspended sediment data available for this study were collected between 1957 and 1962. Are the watershed conditions similar under existing conditions? This question can best be answered by initiating a new sediment measurement program. The sensitivity study demonstrated that deposition magnitudes downstream from Coleman Avenue depend on the wash load concentration in the Guadalupe River upstream. Equally important are suspended bed-material load measurements. Most of the bed-material sediment will move at higher discharges when flow velocity is high. To obtain adequate sediment samples, the sediment sampler will have to be heavy enough to get close to the bed. The collection process may require a stay-line and specialized sampling equipment. Specialists from the USGS should be employed to conduct the sampling program. The program must include laboratory analysis to determine grain size distributions to be useful for sedimentation studies.

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14. ABSTRACT
A numerical model study was conducted to evaluate the potential impact that the Guadalupe River flood-control project would have on channel stability in terms of channel aggradation and degradation. Potential sedimentation problems were determined by evaluating existing data and using the HEC-6W one-dimensional numerical sedimentation model. The numerical sedimentation study quantified the effects of proposed project features on potential aggradation and degradation in the project reach and compared those effects with those calculated for existing conditions. Sedimentation effects were determined for several flood hydrographs and a long-term hydrograph. Data were insufficient to develop a calibrated numerical model that could be used to produce reliable quantified predictions of channel response. However, sensitivity of the numerical model predictions to boundary conditions were determined so that channel responses with and without the project could be compared with confidence. Specific areas of concern were: (a) sediment deposition downstream from bypass inlets during flood events, (b) increased degradation in the channel downstream from bypass inlets where relatively sediment-free flow would be returned to the channel, and (c) increased degradation in reaches where bypasses would not reduce channel flows. Due to limited resources, the study was conducted using available data.

15. SUBJECT TERMS

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